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PRIORITY OF SERVICE QUALITY INFLUENCES ON PATIENTS’ SATISFACTION USING ANALYTIC HIERARCHY PROCESS: THE NIGERIA EXPERIENCE

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Abstract

This paper proposed the use of Analytic Hierarchy Process (AHP) for the prioritization of factors influencing patients’ satisfaction with service quality dimensions of public teaching hospitals in Southwest Nigeria. To accomplish this purpose, data were collected from 326 respondents who were patients of public teaching hospitals in southwest Nigeria. The data were modeled and analyzed with AHP excel software. The results show the rank of service quality dimensions criteria and the alternatives based on the respondents preferences for satisfaction. The finding revealed that empathy dimension criteria were given the highest preference while the waiting time dimension was the least preferred. In the global ranking of all the decision alternatives of the service quality dimensions of hospitals, the interaction of patients with hospital staff were given highest preference while the least preferred were the unpredictable time for treatment. This study recommends that there is need for healthcare managers to consider the perception of patients towards service quality dimensions alternatives on how they ranked those factors so as to improve their quality of service that would enhance patient satisfaction.

Keywords: Patient satisfaction, Analytic Hierarchy Process, service quality, healthcare delivery.

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1. Introduction

The importance of providing a responsive, quality healthcare delivery and understanding patient satisfaction is widely acknowledged in developed and developing countries. Healthcare service quality is an indicator aiding the discovering of the aspects of service quality that require changes to improve patient satisfaction (Jackson and Kroenke 1997). The importance of patients’ views as an essential tool for monitoring and managing as well as improving service quality has been stressed by many studies. Seeking patients’ opinion while providing treatment improves their responses to respective treatment (Ahmed, Amir and Haran 2004).

Satisfaction surveys done in some developed countries showed greater satisfaction and quality of care from patients whose views were sought in tertiary institutions (Asekun-Olarinmoye, Bamidele, Egbewale, Asekun-Olarinmoye and Ojofeitimi 2009; Benjamin, 1999). This is in line with one of objective of health care team to provide the best quality of health care and service to patient in Qatar (Emadi, Falamarzi, Al-Kwuwari and Al-Ansari 2009). Peprah (2013) argues that for the limited healthcare resources to be allocated and managed effectively, it is therefore prudent for healthcare providers to access and identify patients’ priorities among various service quality dimensions and to improve these dimensions for patient satisfaction. Despite various studies done in assessing the quality of services rendered by the hospitals in developing country like Nigeria, to the best of the researchers’ knowledge, there is rarity of literature that has explored the use of Analytic Hierarchy Process (AHP) in prioritizing the service quality dimensions of teaching hospitals in Nigeria. Thus, the aim of this study is to prioritize factors influencing service quality dimensions of public teaching hospitals in Nigeria using AHP and proffer strategies for improving health care service delivery so as to achieve higher level of patients’ satisfaction in Nigeria.

AHP is a widely used multi-criteria decision making tool. Unlike the conventional methods, AHP uses pair-wise comparisons which allow verbal judgments and enhances the precision of the results. The pair-wise comparisons are used to derive accurate ratio and scale priorities developed by Saaty (1980), AHP provides a proven, effective means to deal with complex decision making and can assist in identifying and weighing criteria, analyzing the data collected and expediting the decision-making process (see Adebiyi, Oyatoye and Amole, 2015; Oyatoye Adebiyi and Amole, 2015). This study is very significant in the way it expands the frontier of knowledge on how to enhance health care delivery, increase patient satisfaction as well as contributes to the body of literature that dwell with the application of operations research models to health sector.
The rest of the paper is organized as follows. In the next section, relevant literature on service quality with reference to medical services is reviewed. While the subsequent section describes the methodology used. Thereafter the result of the study were analysed and discussed. The paper finally concludes based on findings and made recommendations.

2. Literature Review

The study of Gotlieb, Grewal, and Brown (1994), explored patient discharge, perceived hospital service quality and satisfaction, and identified evidence of a clear distinction between perceived service quality and patients’ satisfaction. In this way, they found out that patients’ satisfaction mediated the effect of perceived service quality on behavioural intentions, which include adherence to treatment regimes and following provider’s advice. However, Cleary and Edgman-Levitan (1997) pointed out that satisfaction surveys in the health care sector did not measure quality of care, as they did not include important aspects of care items such as being treated with respect and being involved in treatment decisions. In addition, Taylor (1999) noted that confusion continued in the sector regarding the difficulty in differentiation of service quality from satisfaction and reported that some authors, like Kleinsorge and Koenig (1991), referred to them as synonymous terms. Despite this, patients’ satisfaction continues to be measured as a proxy for patient’s assessment of service quality (Turris, 2005).

Andaleeb (2008) studied patient satisfaction (measured by using factor analysis). This study was conducted on caregivers who had accompanied a child came to a hospital in Dhaka. A regression model was constructed by using factor analysis based upon the five dimensional SERVQUAL model. The model explained 67.4% of the variation in the patients’ satisfaction which was taken as the dependent variable. The behavior of the nurses, the behavior of the doctors and facilitation payments (staff expectation of extra payment for normal services that were provided to the patients) had been appeared as statistically significant determinants of patients’ satisfaction. Tangibles composite (all the items that were related to the cleanliness of the hospital and staff) and input adequacy (availability of medicines and equipment whenever needed), appeared as statistically insignificant.

Karassavidou, Glaveli and Papadopoulos (2009) aimed to identify the service quality dimension used by patients for service quality evaluation in Greek NHS (National Services Hospitals). A SERVQUAL questionnaire, including an expectation and perception section, each consisting of 26 statements having seven
point Likert scale was used for the survey. A survey of 137 patients was conducted in six hospitals located in Northern Greece. In this study, principal component method was used to extract factors. Factor analysis resulted in three extracted factors. Alpha coefficient ranged from 0.785 to 0.996 and confirmed the reliability of all three dimensions. Gap analysis was also performed to determine the degree to which the difference between expectations and perceptions exist among patients surveyed.

In the study of Mejabi and Olujide (2008), they provided insight into the nature and characteristics of consumer focused service quality, as it pertains to the Nigerian hospital setting, through identifying a workable measurement scale and determining the underlying service quality dimensions. Two teaching hospitals were used. The instruments had a battery of 39 consumer focused service quality attributes on which respondents rated the hospital on importance and performance. The dimensions were confirmed through factor analysis of importance data, performance data and computed quality data. The results indicated that eight dimensions - resource availability, quality of care, condition of clinic/ward, condition of facility, quality of food, attitude of doctors and nurses, attitude of non-medical staff and waiting time for service, best described the service quality phenomena, producing Cronbach-alpha reliability coefficients of 0.74 to 0.94.

According to Ahmed and Samreen (2011) aimed at evaluating the performance of some selected hospitals in Karachi on the basis of the SERVQUAL model related to customer service quality. For this purpose, data was collected from 252 outpatients visiting three selected hospitals each from public sector, private sector and semipublic sector. Factor analysis was used to extract the important factors on the basis of responses obtained from patients. The factor analysis result indicated five factors which are tangibility and professionalism, reliability & responsiveness, assurance and empathy, feedback and guidance, affordability. Based on these factors, regression models were obtained for all three hospitals. These models have the predictors that are statistically significant determinants of the patients’ satisfaction for each hospital.

Umar, Oche and Umar (2011) researched the patient waiting time in tertiary institution; through a study conducted in the Northern part of Nigeria. They observed that the amount of time a patient waits to be attended to is one factor which affects the utilisation of health care services. Patient satisfaction has emerged as an increasingly important parameter for assessing the quality of health care; therefore, health care facility performance can be best assessed by measuring the level of patient’s satisfaction. In this study also, a cross-sectional descriptive study was carried out at the outpatients’ departments of the Uthman Danfodio University, Sokoto. Here a total of 384 new patients were randomly selected. Furthermore, a set of pre-tested
questionnaires was used to extract information from the respondents while descriptive statistics was used for analysis. In all, a total of 118 (31%) of the patients waited for less than an hour in the waiting room, while 371 (96.6%) spent less than 30 minutes with the doctor. More than half, 211 (55%) of the respondents were satisfied with the service delivery in the hospital, while only 63 (16%) of the respondents admitted to being given health talks while waiting to be attended to by the doctor. Although majority of the patients waited for more than one hour before being attended to, more than half of them were, however, satisfied with the services rendered to them. It is imperative, therefore that health care institutions and providers put in place measures aimed at reducing waiting time and ensuring patients’ satisfaction.

Obamiro (2013) examined the effects of waiting time on patients’ satisfaction in Nigerian hospitals. It discussed the relationship between waiting time and patients’ satisfaction. In so doing, data was obtained through structured questionnaire distributed to a randomly selected 240 outpatients of the selected public and private health centres so as to ascertain their views with regards to waiting time and evaluation of level of satisfaction with service delivery. The data obtained were in turn analysed using descriptive statistics. This study revealed that a good number of patients were satisfied with the service delivery, despite experiencing long waiting time. Though, lengthy waiting line is rampant in the public hospitals than in the private ones. However, this does not affect patients perception of quality care offered because long waiting time is a general occurrence in Nigerian hospitals especially in publicly funded health centers. Based on the findings, Obamiro concluded that efforts should be made by hospital administrators and medical personnel to eliminate unnecessary delay in service delivery and where unavoidable; the waiting time should be made productive. In addition, emphasis should be directed toward the training of medical personnel on ways to create patient-oriented services and deliver more efficient services.

Peprah and Atarah (2014) assessed patients’ satisfaction using SERVQUAL model in Suyani Regional hospital in Ghana. The SERVQUAL instrument was adapted and modified to capture the relevant data. A total of 214 patients were employed in the study. Data were analysed using SPSS (version 16.0) for descriptive statistics and patients satisfaction were determines by the services quality gap model. The result indicated that the overall satisfaction of patients concerning the service quality of the hospital was good. On the other hand the gap scores showed negative gaps for four of the service quality dimensions out of six used in the study, indicating that patients were not satisfied with the service quality in relation to those dimensions. This therefore calls for management action to improve service delivery in those areas. These dimensions
were Reliability, Communication/interpersonal relationship, Assurance, and Responsiveness. On the contrary, Tangibility and Empathy dimensions scored positive which affirms patients’ impression about the service.

Umeano-Enemuoh, Onwujekwe, Uzochukwu and Ezeoke (2014) examined patients’ satisfaction and quality of care in tertiary institution in Southeast Nigeria. In their contribution, they aim to determine the factors which enhance and deter patients’ satisfaction in a tertiary institution and the quality of care. To do this, the study used a cross sectional survey design in which 360 carefully selected participants completed self-administered questionnaire to rate their satisfaction level, quality of services provided, as well as factors of importance where best service was provided. Overall, participants were quite satisfied (Mean score = 3.75) with the services provided by the different service providers. Equally, respondents also noted that the overall quality of care of the health facility was good (mean score = 3.45). Pharmacy received the highest satisfaction level with a mean rating of 4.1. Over a third participants (38%) rated the services provided by the doctors as best despite giving the highest quality ratings with a mean of 3.9 to pharmacy compared to mean ratings of 3.4 for the doctors. In the same vein, respondents’ greatest displeasure was with the time spent at the facility as 63.9% of them were displeased. More than a third (36.9%) of the patient was most pleased with information given to them as a factor of importance. Moreover, participants were quite satisfied with the services provided as well as the quality of care by the different service providers of the health facility. As a consequence, it was concluded that there is need for interventions in terms of time spent at the facility which would promote good customer focused service delivery.

Based on the review of literature so far, there is limited study that has been able to prioritize the factors influencing the service quality dimensions of teaching hospitals using the Analytic Hierarchy Process technique which this study set out to do and proffer effective strategies for improving the health care service delivery in Nigeria.

3. Methodology

This study employed cross sectional survey research design. The study covers all the public teaching hospitals in southwest geopolitical zone of Nigeria. The public teaching hospitals in the zone are: Lagos University Teaching Hospital (LUTH), Iddi-Araba; Lagos State University Teaching Hospital (LASUTH), Ikeja; Olabisi Onabanjo University Teaching Hospital (OOUTH), Sagamu; University College Hospital (UCH), Ibadan; Obafemi Awolowo University Teaching Hospital (OAUTH), Ile-Ife; Ladoke
Akintola University Teaching Hospital (LAUTH), Osogbo; and Ekiti State University Teaching Hospital (EKSUTH), Ado–Ekiti. Purposive sampling technique was used to select six public teaching hospitals in southwest Nigeria. Random sampling technique was used to distribute copies of questionnaire to 420 patients who had received services from the public teaching hospitals within a year. That is 70 patients representing each of the public teaching hospital in south west Nigeria. Out of the copies of questionnaire distributed 326 copies of questionnaire were found useful for the analysis. Figure 3.1 shows hierarchical model of the hospital service quality assessment which include the main goal which is determinant of patients’ satisfaction with respect to the service quality dimensions of hospitals. The criteria are the seven service quality dimensions and the alternatives.

The AHP analysis was done using Microsoft Excel software with specific instructions to make it adaptable to the analysis. The value for calculation in the AHP method is acquired from the questionnaires that have been filled by respondents/patients. The process of analysis by using the AHP method is done in two stages as follows (Taylor III, 2002):

(i) First Stage: Determinant of patients’ satisfaction with hospitals service quality dimensions: (a) Establishing the Pairwise Comparison Matrix for each decision alternative and for each criterion, (b) Synthesisation, (c) Establishing the Pairwise Comparison Matrix for each of the criteria, (d) Establishing the Normalised Matrix, (e) Establishing the Preference Vector (f) Calculating overall values for each decision alternative, and (g) Determining the rank of alternatives according to the values that have been acquired in the previous stage.

(ii) Second Stage: Test of Consistency, after analysng the data by using the AHP method, the result of the selection process must be tested for consistency. The test of consistency is done by using the following formulae:

(iii)\[
CI = (\lambda_{Max} - n)/(n - 1) \tag{3.1}
\]

Where \( \lambda_{Max} = \sum wi ci \)

After acquiring Consistency Index (CI), the next step is calculating Consistency Ratio (CR) by using formula

\[
CR= \frac{CI}{RI} \tag{3.2}
\]
Figure 3.1 Hierarchical model for hospital services quality assessment

- **CHE** - Cleanliness of the hospital environment
- **HPAN** - Hospital’s personnel appears neat
- **UDME** - Up to date Medical Equipment
- **PF** - Physical facilities are usually appealing
- **AMR** - Accuracy of Medical Report
- **AME** - Accuracy of Medical Expenses
- **ERPP** - Employees Respect Patients Privacy
- **PAIPMC** - Provision of Adequate Information about Patient Medical Condition
- **PS** - Prompt Service
- **WASPQ** - Willingness of Administrative Staff to Attend to Patient Queries
- **STPE** - Hospital staff tell patient exactly when services will be performed
- **PFSE** - Patient feel safe in their interaction with employees
- **PMF** - Proficient Medical Staff
- **HEAP** - Hospital Employees are Polite
- **UTFD** - Employee Understanding Towards Feelings of Discomfort
- **EPBIH** - Employees keep Patient Best Interest at Heart
- **WCA** - Warm and Caring Attitude
- **AIP** - Adequate Information for Patient
- **DAI** - Doctors give Adequate Instruction
- **TPICT** - Taking Patient Opinion into consideration in Treatment
- **WTIP** - Waiting Time is Important to Patient
- **WTHP** - Waiting Time at the Hospital is Predictable
- **HTWM** - Hospital tries to Keep Waiting time to a Minimum
Prioritization of service quality influences on patients’ satisfaction using analytic hierarchy process: the Nigeria experience

Where:

\[ n = \text{Number of items compared} \]
\[ W_i = \text{Weight} \]
\[ C_i = \text{Sum along column} \]
\[ CR = \text{Consistency Ratio} \]
\[ CI = \text{Consistency Index} \]
\[ RI = \text{Random Consistency Index} \]

The Random Consistency Index (RI) can be observed in Table 3.1 as follows:

\[
\begin{array}{cccccccccccccc}
N & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 \\
R.I. & 0 & 0 & 0.58 & 0.90 & 1.12 & 1.25 & 1.32 & 1.41 & 1.45 & 1.49 & 1.54 & 1.48 & 1.56 & 1.57 & 1.59 \\
\end{array}
\]

Adapted from Saaty, (2000)

If \( CR \geq 10\% \), the data acquired is inconsistent
If \( CR < 10\% \), the data acquired is consistent.

4.0 Results and Discussion

\[
Table 4.1
\]

Summary of the social economic characteristics of the respondents

<table>
<thead>
<tr>
<th>Variables</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>145</td>
<td>44.5</td>
</tr>
<tr>
<td>Female</td>
<td>181</td>
<td>55.5</td>
</tr>
<tr>
<td>Total</td>
<td>326</td>
<td>100</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-25years</td>
<td>120</td>
<td>36.8</td>
</tr>
<tr>
<td>26-35yrs</td>
<td>63</td>
<td>19.3</td>
</tr>
<tr>
<td>36-45yrs</td>
<td>77</td>
<td>23.6</td>
</tr>
<tr>
<td>46 and above</td>
<td>66</td>
<td>20.2</td>
</tr>
<tr>
<td>Total</td>
<td>326</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 4.1 shows the social economic characteristics of the respondents. It reveals that 145 (44.5%) of the respondents were males, while 181 (55.5%) were females. Two hundred and sixty (260) or 80% of them were between 18-40 years of age, while 66 (20%) were above 45 years of age; 98 (30.1%) respondents were SSCE Degree holders, 23 (7.1%) were NCE/ND certificate holders, 180 (55.1%) were HND/BSC/BA degree holders; 9 (2.8%) were MBA/M. Sc/ M.Ed. degree holders while 16 (4.9%) had other qualification. With regards to filling the questionnaire, 274 (84%) respondents did it themselves, while the remaining 52 (16%) respondents were assisted by their children, spouse, and other relatives. With respect to the reason for
visiting the hospital, 156 respondents (47.9%) came for medical treatment, 80 (24.5%) respondents came for advice, 77 (23.6%) respondents came for routine checkup, and 13 (4%) respondents came for other reasons known to them.

4.1 Composite Priorities

The Analytic Hierarchy Process model deployed for this study has three levels: The goal, the criteria, and the alternatives. The priorities for the patients critical preference of the factors that determine their satisfaction towards the quality of service rendered in the selected teaching hospitals in Southwest, Nigeria are presented in Tables 4.2 to 4.9.

4.1.1. Analysis of alternatives with respect to the criteria

Table 4.2 shows the patients’ perception with regards to decision alternatives of tangibility dimension using the composite priorities. The most preferred alternative under the tangibility is up-to-date medical equipment with a priority of 0.3938, followed by the cleanliness of the hospital environment with a priority of 0.2525. Next is ‘hospital personnel appears neat’ with a priority of 0.2300, while the least preferred alternative is the ‘physical facilities’ with priority of 0.1237.
Table 4.3

Composite priorities of the decision alternative about reliability dimension

<table>
<thead>
<tr>
<th>Decision alternative with regards to reliability dimension</th>
<th>Accuracy of medical report (AMR),</th>
<th>Accuracy of expense report (AER)</th>
<th>Employees Respect Patients Privacy (ERPP)</th>
<th>Provision of Adequate Information about Patient Medical Condition (PAIPMC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled Average Composite priority</td>
<td>0.3843</td>
<td>0.1685</td>
<td>0.2351</td>
<td>0.2120</td>
</tr>
<tr>
<td>Relative preference ranking</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Survey Research (2014).

Table 4.3 displays the patients’ perception with regards to decision alternative of reliability dimension. The most preferred alternative under the reliability dimension is the ‘accuracy of medical report’ (AMR) with a priority of 0.3843. This is followed by employees respect patients privacy with a priority of 0.2351, “provision of adequate information about patient medical conditions” has a priority of 0.2120 and the least preferred is the ‘accuracy of expense report’ (AER) with a priority of 0.1685.

Table 4.4

Composite priorities of the decision alternative with regards to responsiveness dimension

<table>
<thead>
<tr>
<th>Decision alternative with regards to responsiveness dimension</th>
<th>Prompt Service</th>
<th>willingness of administration staff to attend to patients queries (WASPQ)</th>
<th>Hospital Staff tell Patient exactly when services will be performed (STPE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled Average Composite priority</td>
<td>0.5411</td>
<td>0.3111</td>
<td>0.1478</td>
</tr>
<tr>
<td>Relative preference ranking</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Survey Research (2014).
Table 4.4 reveals patients’ perception with regards to the decision alternatives of responsiveness dimension using composite priorities. This dimension has three alternatives in this study. Patients’ mostly preferred ‘prompt service’ with a priority of 0.5411, followed by ‘willingness of administration staff to attend to patients’ queries’ (WASPQ) with a priority of 0.3111, and the least preferred is the ‘hospital staff to inform patient exactly when services will be performed’ with a priority of 0.1478.

Table 4.4

<table>
<thead>
<tr>
<th>Decision alternatives with regards to responsiveness dimension</th>
<th>Patient feel safe in their interaction with employees (PFSE)</th>
<th>Hospital employees are polite (HEAP)</th>
<th>Proficient medical staff (PMF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled Average Composite priority</td>
<td>0.6329</td>
<td>0.2171</td>
<td>0.1500</td>
</tr>
<tr>
<td>Relative preference ranking</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Survey Research (2014).

Table 4.5

Composite priorities of the decision alternatives with regards to assurance dimension

Table 4.5 shows patients’ perception with regards to the decision alternatives of assurance dimension using the composite priorities. The most preferred alternatives under the assurance dimension is that ‘patient feel safe in their interaction with employees’ (PFSE) with a priority of 0.6329. This is followed by ‘hospital employees are polite’ (HEAP) with a priority of 0.2171 and the least preferred is the ‘proficient medical staff’ (PMF) with a priority of 0.1500.

Table 4.6

Composite priorities of the decision alternatives with regards to empathy dimension

Table 4.6

<table>
<thead>
<tr>
<th>Decision alternatives with regards to empathy dimension</th>
<th>Warm and Caring Attitude (WCA)</th>
<th>Employees understanding towards feelings of discomfort (EUFD)</th>
<th>Employees keep Patient Best Interest at Heart (EPBIH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled Average Composite priority</td>
<td>0.5287</td>
<td>0.2933</td>
<td>0.1780</td>
</tr>
<tr>
<td>Relative preference ranking</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Survey Research (2014).
Table 4.6 shows patients’ perception with regards to the decision alternatives of empathy dimension. This dimension has three decision alternatives in this study. The most preferred alternatives under the empathy dimension is `warm and caring attitude` with a priority of 0.5287, followed by `employees understanding towards feelings of discomfort` (EUFD) with a priority of 0.2933 and `employees keep patient best interest at heart` (EPBIH) with a priority of 0.1780.

Table 4.7

<table>
<thead>
<tr>
<th>Composite priorities of the decision alternatives with regards to effective communication dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision alternatives with regards to effective communication dimension</strong></td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pooled Average Composite priority</td>
</tr>
<tr>
<td>Relative preference ranking</td>
</tr>
</tbody>
</table>

Source: Survey Research (2014).

Table 4.7 shows patients’ perception with regards to the decision alternatives of effective communication dimension. The most preferred alternatives under the effective communication dimension are that giving `adequate information to patient` with a priority of 0.4662. This is followed by `doctors giving adequate instruction` with priority 0.3809, while the least preferred is taking `patients’ opinion into consideration in treatment` with a priority of 0.1529.

Table 4.8

<table>
<thead>
<tr>
<th>Composite priorities of the decision alternatives with regards to waiting time dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decision alternatives with regards to waiting time dimension</strong></td>
</tr>
<tr>
<td>------------------------------------------------------------------</td>
</tr>
<tr>
<td>Pooled Average Composite priority</td>
</tr>
<tr>
<td>Relative preference ranking</td>
</tr>
</tbody>
</table>

Source: Survey Research (2014).
Table 4.8 shows the patients’ perception with regards to the decision alternatives of waiting time using composite priorities. This dimension has three decision alternatives. The most preferred alternatives under the waiting time dimension is ‘waiting time is important to patient’ (WTIP) with a priority of 0.5755, followed by ‘hospital tries to keep waiting time to a minimum’ (HTWM) with a priority of 0.2182 and the least preferred is ‘waiting time at the hospital is predictable’ (WTHP) with a priority of 0.2063.

**Composite priorities of the criteria with regards to Goal**

<table>
<thead>
<tr>
<th>Goal: Patients perception towards service quality</th>
<th>Tangibility</th>
<th>Reliability</th>
<th>Responsiveness</th>
<th>Assurance</th>
<th>Empathy</th>
<th>Effective communication</th>
<th>Waiting time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled Average Composite Priority</td>
<td>0.1619</td>
<td>0.1560</td>
<td>0.1562</td>
<td>0.1435</td>
<td>0.1646</td>
<td>0.1480</td>
<td>0.0698</td>
</tr>
<tr>
<td>Relative Preference Ranking</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

*Source: Survey Research (2014).*

Table 4.9 shows the priorities of the criteria with respect to the main goal which is to determine patients’ satisfaction towards quality of services rendered in the teaching hospital. This is done by considering the five generic dimensions of service quality as propounded by Parasuraman Berry and Zeithaml (1991), and two additional important dimensions namely: effective communication and waiting time which are equally important to patients in determining their satisfaction with hospitals. Based on the perception and pairwise comparison of the patient the most important factor which determines their satisfaction, is the empathy dimension with a priority of 0.1646, followed respectively by the tangibility dimension with a priority of 0.1619, responsiveness dimension with a priority of 0.1562, reliability dimension with a priority of 0.1560, effective communication dimension with a priority of 0.1480, assurance dimension with a priority of 0.1435, while the least determinant factor is the waiting time dimension with a priority of 0.0698.

Following the procedure of AHP analysis using Microsoft excel which is done in two stages as stated under the methodology. This procedure was used to derive individual weight for each of the service quality dimension criteria and also calculate the individual weight of the decision alternatives with respect to the decision criteria. These weights are also known as local priority and it is presented in table 4.10.
### Table 4.10

**Tabular presentation of the decision criteria and alternatives local priority**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Local Priority</th>
<th>Alternatives</th>
<th>Local Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangibility</td>
<td>0.1619</td>
<td>Up-to-date medical equipment (UDME)</td>
<td>0.3938</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cleanliness of hospital environment (CHE)</td>
<td>0.2525</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hospital’s personnel appears neat (HPAN)</td>
<td>0.2300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physical facilities (PF)</td>
<td>0.1237</td>
</tr>
<tr>
<td>Reliability</td>
<td>0.1560</td>
<td>Accuracy of medical report (AMR)</td>
<td>0.3843</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employees respect patients’ privacy (ERPP)</td>
<td>0.2351</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provision of adequate information about patients’ medical condition (PAIPMC)</td>
<td>0.2120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accuracy of expense report (AER)</td>
<td></td>
</tr>
<tr>
<td>Responsiveness</td>
<td>0.1562</td>
<td>Prompt service (PS)</td>
<td>0.5411</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Willingness of the administration staff attend to patients queries (WASPQ)</td>
<td>0.3111</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hospital Staff tell Patient exactly when services will be performed (STPE)</td>
<td>0.1478</td>
</tr>
<tr>
<td>Assurance</td>
<td>0.1435</td>
<td>Patient feel safe in their interaction with employees (PFSE)</td>
<td>0.6329</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hospital Employees are Polite (H EAP)</td>
<td>0.2171</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proficient medical staff (PMF)</td>
<td>0.1500</td>
</tr>
<tr>
<td>Empathy</td>
<td>0.1646</td>
<td>Warm and Caring Attitude (WCA)</td>
<td>0.5287</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employees understanding towards feelings of discomfort (EUFD)</td>
<td>0.2933</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employees keep patient best interest at heart (EPBIH)</td>
<td>0.0173</td>
</tr>
<tr>
<td>Effective</td>
<td>0.1480</td>
<td>Adequate Information for Patient (AIP)</td>
<td>0.4662</td>
</tr>
<tr>
<td>Communication</td>
<td></td>
<td>Doctors give Adequate Instruction (DAI)</td>
<td>0.3809</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Taking patient opinion into consideration in treatment (TPCIT)</td>
<td>0.1529</td>
</tr>
<tr>
<td>Waiting time</td>
<td>0.0698</td>
<td>Waiting Time is Important to Patient (WTIP)</td>
<td>0.5755</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hospital tries to keep waiting time to a minimum (HTWM)</td>
<td>0.2182</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waiting time at the hospital is predictable (WTHP)</td>
<td>0.2063</td>
</tr>
</tbody>
</table>

*Source: Data Analysis 2014.*
Table 4.10 shows the individual local weight of the service quality dimension criteria and the local weight of the decision alternatives with respect to the service quality dimension criteria. These local weights of the decision criteria and alternatives were now used to calculate the total weight or global weight/priority.

**Computation of the global weight**

When the weight among elements on every level is derived, the weight of the whole level is calculated. In AHP, it is observed that each level in the hierarchy is independent of the other. This implies that the probability multiplicative law holds. Moreover, the total weight of each alternative was calculated by multiplying the weight of decision criteria by decision alternative weight.

**Table 4.11**

*Tabular presentation of the decision alternatives with their corresponding global /total weight*

<table>
<thead>
<tr>
<th>Decision Alternatives</th>
<th>Total/ Global Priority</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up-to-date medical equipment (UDME)</td>
<td>0.0638</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cleanliness of hospital environment (CHE)</td>
<td>0.0409</td>
<td>10&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hospital’s personnel appears neat (HPAN)</td>
<td>0.0372</td>
<td>12&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Physical facilities (PF)</td>
<td>0.0200</td>
<td>21&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>Accuracy of medical report (AMR)</td>
<td>0.0600</td>
<td>6&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Employees respect patients’ privacy (ERPP)</td>
<td>0.0367</td>
<td>13&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Provision of adequate information about patient medical condition (PAIPMC)</td>
<td>0.0331</td>
<td>14&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Accuracy of expense report (AER)</td>
<td>0.0263</td>
<td>17&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Prompt service (PS)</td>
<td>0.0845</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Willingness of the administration staff attend to patients queries (WASPQ)</td>
<td>0.0486</td>
<td>8&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hospital Staff tell Patient exactly when services will be performed (STPE)</td>
<td>0.0231</td>
<td>18&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Patient feel safe in their interaction with employees (PFSE)</td>
<td>0.0908</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hospital Employees are Polite (H EAP)</td>
<td>0.0311</td>
<td>15&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Proficient medical staff (PMF)</td>
<td>0.0215</td>
<td>20&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Warm and Caring Attitude (WCA)</td>
<td>0.0870</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Employees understanding towards feelings of discomfort (EUFD) | 0.0483 | 9th
Employees keep patient best interest at heart (EPBIH) | 0.0293 | 16th
Adequate Information for Patient (AIP) | 0.0690 | 4th
Doctors give Adequate Instruction (DAI) | 0.0564 | 7th
Taking patient opinion into consideration in treatment (TPCIT) | 0.0226 | 19th
Waiting Time is Important to Patient (WTIP) | 0.0402 | 11th
Hospital tries to keep waiting time to a minimum (HTWM) | 0.0152 | 22nd
Waiting time at the hospital is predictable (WTHP) | 0.0144 | 23rd

**Figure 4.1. Bar chart showing decision alternatives with their corresponding priority**

The vertical bar-chart in figure 4.1 represents the pictorial diagram of decision alternatives where the vertical bar length is the priority of each alternative. From the chart, it can be seen that patient feeling safe in their interaction with the hospital employees has the longest bar with priority of 0.0908. This is followed by warm and caring attitude with pr (0.0870), prompt service with pr (0.0845), adequate information to patients with pr(0.0690), up-to-date medical equipment with pr(0.0638), accuracy of medical report with pr (0.0600), doctors give adequate instruction with pr(0.0564), willingness of administration staff to attend to patients queries with pr(0.0486), employee understanding towards feelings of discomfort with
Prioritization of service quality influences on patients’ satisfaction using analytic hierarchy process: the Nigeria experience

pr(0.0483), cleanliness of hospital environment with pr(0.0409), waiting time is important to patient with pr(0.0402), hospital personnel are neat with pr (0.0372), employee respect patients’ privacy with pr(0.0367), provision of adequate information about patient medical condition with pr(0.0331), hospital personnel are polite with pr (0.0311) in that order. From the chart, waiting time at the hospital has the shortest bar with pr(0.0144), followed by hospitals tries to keep the waiting time to barest minimum with pr(0.0152), physical facilities with pr(0.0200), proficient medical staff with pr(0.0215), taking patients opinion into consideration in treatment with pr(0.0226) and then accuracy of medical expenses with pr(0.0263). These priorities must sum up to one, thereby satisfying the law of probability.

5. Conclusion and recommendations

The patients have been able to prioritize the service quality dimensions of hospitals in order of importance in which the policy-maker or health administrators could abide by in order to improve the quality of health care delivery and enhance patients’ satisfaction.

The result of the Analytic Hierarchy Process (AHP) model showed that among the seven dimensions of service quality of hospital which were the criteria identified in determining the patient satisfaction, the empathy dimension was rated the highest. This indicated that the patients were most satisfied with the warm and caring attitude of the hospital staff. The second highest ranked was the tangibility dimension which showed that patients were satisfied with having up-to-date medical equipment in the hospitals, compared to cleanliness of the hospital environment. The third dimension that was rated next was the responsiveness dimension which indicated that patients believed that giving prompt services to them in the hospital is paramount, followed by the reliability dimension because patients believed that the teaching hospitals gave accurate medical report when needed. Followed by effective communication dimension which showed that adequate information for the patients is essential compared to others, followed by assurance dimension which showed that patients feel safe in their interaction with the employees of the hospital is most important compared to others, while waiting time dimension was rated the least satisfying, and indicates that the waiting time of the patient before service is still an issue which corroborated the views of Umar et al (2011), Obamiro (2013), and Umeano-Enemuoh et al (2014). AHP is therefore useful in structuring the complexity of health care decisions and ascertaining values and preferences of those factors involved in health care decision-making. Previous studies in Nigeria which had used the method in
health sector were limited to prioritizing the management function in the pharmaceutical industry (Ogunyemi, Ibiwoye and Oyatoye, 2011).

In ranking all the decision alternatives of the service quality dimension, the alternative that has the highest preference was patient feeling safe in their interaction with the employees, while the least preferred was predicting the waiting time, indicating that majority of the patients are satisfied with their interaction with the employees, but cannot predict the time services would be rendered. There is need for healthcare managers to consider the perception of patients towards service quality dimensions alternatives on how they have been able to rank those factors so as to improve their quality of service that would enhance patient satisfaction. In addition, the priority and the ordering of healthcare service quality dimensions from the patient perspective will enhance international best practices through policy implementation that stimulate patients’ satisfaction by meeting their service needs.

References


The article presents the results of a study of the relation between education and the duration of unemployment on a labour market functioning in different economic conditions. The aim of the study is to examine the degree of influence of the level of education on the chance of long-term unemployment under conditions of a balanced and a destabilized in time of economic crisis labour market. The estimation of the effect of the impact of the level of education on the duration of unemployment has been accomplished on the basis of individual data on the economically active individuals, gathered by means of the sample "Survey of the Labour Force" conducted by the National Statistical Institute. The data on the unemployed persons and their socio-demographic characteristics are as of the fourth quarter of 2008 and the fourth quarter of 2013 and include 14,971 and 14,652 monitored individuals, respectively. Using logistic regression it has been ascertained that the relation between education and the duration of unemployment of the persons who are out of work manifests itself clearly under a stable labour market. In an unstable economic environment the effect of the impact of the education on the duration of unemployment decreases to insignificant levels. The existence of a disequilibrium between the demand and supply on the labour market in a period of economic instability obliterates the role of the higher education level for reducing the duration of unemployment of the persons who are out of work.

Keywords: education, short-term and long-term unemployment.

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Introduction

Education is a principal characteristic of the workforce, defined as a leading factor for the successful career placement of the economically active individuals on the labour market. It can be expected, however, that the role of this factor is manifested in different ways under conditions of stable economic environment and during periods of economic instability, accompanied by an imbalance of the labour market. The study of the role of education in that aspect would provide information on the connection between the parameters of the economic environment as well as the degree and direction of the influence of the economically active persons' educational level on their realization on the labour market. That kind of analysis would ensure the basis for the shaping of a flexible policy and the adoption of effective mechanisms for influencing the labour market under conditions of unstable economic environment. It would create the opportunity to predict in what direction the effect of education would change under adversely altered parameters of the economic environment in which the labour market functions.

The effect of the impact of the economically active persons' education on their possibilities for realization on the labour market can be assessed in different areas. Along with the main connection - that between education and the belonging of the individuals to one of the two components of the supply on the labour market (employed and unemployed persons), of certain interest is also the connection between the education of the unemployed persons and the length of time during which they are unemployed. It is known that in times of economic instability there is an increase not only in the overall rate of unemployment, but also in its duration. Long-term unemployment is a serious social problem and part of it can be solved successfully, if the factors which affect it are identified. One of these factors might be the educational level of the unemployed on the labour market. The scientific interest in the impact of this factor has instigated the conducting of a number of studies aimed at gaining empirical evidence on the role of education for the successful career placement on the labour market. A study of the labour market in Greece has found that the level of education has no effect on the probability of unemployment (Livanos 2009), or on the chance of short-term or long-term unemployment (Livanos 2007). Based on individual data from the observation of the labour force in Turkey in 2000 and 2001, and by means of probit models there is found a substantial impact of education on the duration of unemployment of the unemployed persons (Tasci, Ozdemir 2006). A study of the factors of long-term unemployment in Greece by way of logistic regression leads to the conclusion that most vulnerable with respect to long-term unemployment are
the persons with low level of education (Daouli, Demoussis 2015). The opposite result is obtained in a study of the factors of the duration of unemployment in Argentina for the period 1998-2005. By means of a multinomial probit model it is established that the duration of unemployment is greater with the persons possessing a higher level of education (Canavire-Bacarreza, Soria 2007). Using parametric and non-parametric methods (Proportional Hazard Model, Log-Logistic and Log-Normal Model), Tansel and Tasci (2005) demonstrate that the probability of unemployment in Turkey decreases with the increase in the level of education of the economically active persons. According to another study based on the use of Survival Analysis for assessing the effect of education on the duration of unemployment, the individuals having higher education remain out of a job on average for a period of 5 months, whereas with the individuals without education this period averages 13 months (Dănăcică, Babucea 2007). By means of Survival Analysis the duration of unemployment is assessed, as well as the factors, which affect it in certain districts in Romania (Ciura, Matei 2010). The results of the study show that the percentage of long-term unemployed persons is affected by a number of socio-demographic factors, including education, each district featuring a different impact model.

The diverging results of the studies lead to the conclusion that education has an essential role in reducing the duration of unemployment, but that role has various manifestations. It is determined by the specific economic conditions in which the labour market functions. The parameters of the economic environment influence the direction and the force of the impact of education, which is why that influence cannot be absolutized, but rather has to be studied in the particular conditions of the functioning of the labour market. This insight is particularly important during periods of economic instability and the accompanying disequilibrium of the labour market. It is at the root of the interest of the authors of the present study in the specific character of the impact of education on the duration of unemployment of the persons who are out of work in Bulgaria, under conditions of both a stable economic environment, and one that is subjected to shocks. The aim of the article is to assess the degree of influence of the educational level on the chance of long-term unemployment under conditions of a balanced, and a destabilized in time of economic crisis labour market, and to formulate conclusions regarding the changing role of education under the altered parameters of the economic environment in which the labour market is functioning.
Approach and information basis of the study

The generalized view of the relation between education and the duration of unemployment of the persons who are out of work is presented by means of the conceptual model in Fig. 1. Through the visualization of the relation the model is set as the basis for its analysis, providing the possibility for choosing the most suitable analytical approach and tools. The idea not only to establish the presence of a connection, but also to measure it quantitatively, determines the choice of analytical approach - regression analysis of the relation presented in the conceptual model. The choice of the tools for the realization of the regression analysis in this case is connected with the kind of variables that are studied. Education and the duration of unemployment are presented in the conceptual model by means of two qualitative variables, the second variable being binary scaled. The modelling of the relation between such variables requires the use of regression analysis that is different from the classical type. Suitable for the analysis of variables that have been scaled in this way is the logistic regression.

Fig. 1. Conceptual model of the relation between education and the duration of the unemployment of economically active individuals
The use of logistic models for the description of the relations between education and the duration of unemployment requires certain manipulation of the primary data. The independent variable - level of completed education - is presented on a four-level ordinal scale - primary, basic, secondary and higher education. In order to assess the effect of the impact of each of these categories, it is necessary that they be coded in a certain way. The coding can be done by means of a scheme using fictitious (dummy) variables, which allows for a quantitative measurement of the effects of the impact of the individual categories of the independent variable on the dependent variable. In this case we obtain three dummy variables, which can be presented as follows:

- \( c_1 = 1 \) for "primary education", 0 for all the remaining categories;
- \( c_2 = 1 \) for "basic education", 0 for all the remaining categories;
- \( c_3 = 1 \) for "secondary education", 0 for all the remaining categories;

The last category of the independent variable - "higher education" - is defined as a benchmark, that is, as a sort of a standard, in relation to which there is assessed the impact of each one of the remaining categories of education on the dependent variable. Based on the dummy variables composed in this manner, the logistic model describing the relation between the educational level and the duration of unemployment of the persons who are out of work takes the following form:

\[
\ln \left( \frac{\pi}{1 - \pi} \right) = \beta_0 + \beta_1 c_1 + \beta_2 c_2 + \beta_3 c_3, \tag{1}
\]

where:
- \( \pi \) – probability for success (for fulfilment of the dependent variable);
- \((1 - \pi)\) – probability for failure (for non-fulfilment of the dependent variable);
- \( \frac{\pi}{1 - \pi} \) – chance of success - measures how many times the probability for fulfilment of the dependent variable is greater (smaller) than the probability of it not being fulfilled.
- \( \beta_0, \beta_1, \beta_2 \) and \( \beta_3 \) - parameters of the model;
- \( c_1, c_2 \) and \( c_3 \) - dummy variables for primary, basic and secondary education.

For the evaluation of the model presented above there are used individual data on the economically active persons, collected by means of the sample "Survey of the Labour Force" conducted by the National Statistical Institute. The data on the employed and the unemployed persons and their socio-demographic characteristics are as of the fourth
quarter of 2008 and the fourth quarter of 2013 and include 14,971 and 14,652 monitored individuals, respectively. The choice of the fourth quarter of the two years is based on the consideration that it is a quarter which excludes the seasonal employment and the mobility of the persons and provides a more accurate idea of the actual situation on the labour market. The existence of seasonal employment is clearly shown in the data presented in Fig. 3 on the rate of unemployment by quarter of the respective year - it is highest in the first and the fourth quarter, when the economic activity of seasonal nature is shrunk or suspended. The exception to this trend is 2008, when the unemployment rate permanently falls in all four quarters, and 2009 - with a permanently rising unemployment throughout the whole year. The increase in unemployment - both seasonal, and yearly, continues until 2013, whereupon there is observed a drop in its level (Figs. 2 and 3). This fact, as well as the data on the decreasing gross domestic product of the country (Fig. 4) give us reason to identify the period 2009-2013 as a period of economic crisis, and 2008 - as the last year of economic stability and equilibrium on the labour market, preceding the crisis. In that sense the choice of the years 2008 and 2013 as the basis for the analysis is not an end in itself - they set two heterogeneous - in terms of the situation on the labour market - periods. The comparative analysis of the results obtained for the two years will allow us to formulate conclusions regarding the degree of influence of education on the duration of unemployment and the change in that influence upon destabilization of the economic environment in which the labour market functions.

![Fig. 2 Levels of employment and unemployment in Republic of Bulgaria (%)](image-url)
In order to assess the effect of the impact of the level of education on the duration of unemployment we use the theoretical logistic model, presented by means of equation 1. In this case the values "\( \pi \)" и "\( 1-\pi \)" are the probabilities for long-term and
short-term unemployment respectively, whereas their ratio - \( \frac{\pi}{1-\pi} \) measures the chance of long-term unemployment of the persons who are out of work. The logistic model is developed successively in two variants - based on the sample data from 2008 and 2013. The estimation of the parameters of the first variant of the model using the maximum likelihood method ends at the third iteration, and the logistic model becomes:

\[
\ln \left( \frac{\pi}{1-\pi} \right) = -0.511 + 1.185c_1 + 1.185c_2 + 0.422c_3
\]

The test characteristics of the model prove its adequacy, but the parameter in front of the variable "c_3", representing the category "secondary education", is statistically insignificant at a level of significance 0.05. Exercising a degree of cautiousness we can interpret this parameter contentwise at a level of significance 0.10.

The equality of the parameters in front of the variables "c_1" and "c_2" shows an equal degree of impact of the categories "primary and lower" and "basic education" on the chance of a long-term unemployment of the persons who are out of work. The category "secondary education" does not have considerable influence, a sign of which is the low value of the parameter in front of the variable "c_3" and the greater error with which it is burdened. The positive value of the estimated parameters of the model gives us reason to conclude that the chance of long-term unemployment of the individuals having primary and basic education is greater than that of the individuals with higher education. The direct interpretation of the parameters of the model is difficult to perceive, since their values refer to the logarithm of the chance of long-term unemployment. In order to avoid that inconvenience the model is estimated with respect to the very chance of long-term unemployment of the persons who are out of work:

\[
\frac{\pi}{1-\pi} = e^{-0.511 + 1.185c_1 + 1.185c_2 + 0.422c_3}
\]

The exponential parameter values obtained through the model indicate that the chance of long-term unemployment of the persons out of work having primary and basic education is 3.3 times as great as that of the unemployed persons having higher education. The further development of model (3) provides the opportunity to estimate the probabilities and chances of long-term unemployment of the persons who are out of work.
of work at each particular level of education. The model estimated in that aspect acquires the following form:

$$\pi_{2008} = \frac{e^{(-0.511 + 1.185c_1 + 1.185c_2 + 0.422c_3)}}{1 + e^{(-0.511 + 1.185c_1 + 1.185c_2 + 0.422c_3)}}$$

(4)

The estimation of the parameters of the second variant of the model - using the sample data from 2013 - ends at the third iteration of the maximum likelihood method, and the model is expressed in the following concrete form:

$$\ln \left( \frac{\pi}{1 - \pi} \right) = 0.283 + 0.421c_1 + 0.292c_2 + 0.135c_3$$

(5)

The obtained test characteristic of the model gives us reason to identify it as inadequate, which renders its use for further analysis incorrect. The inadequacy of the model means that the independent variable has no substantial contribution to the formation of the variation of the dependent variable. That is the reason to conclude that in 2013 education exerts no statistically significant influence on the duration of the unemployment of the persons who are out of work. Using the estimated logistic model (4) we can obtain the chances and the probabilities for long-term unemployment depending on the education of the unemployed individuals only for 2008 (Table 1).

**Table 1**

**Chance and probability of long-term unemployment of the persons who are out of work having different levels of education (2008)**

<table>
<thead>
<tr>
<th>Level of completed education</th>
<th>Chance of long-term unemployment ($\pi/1-\pi$)</th>
<th>Probability of long-term unemployment ($\pi$) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary and lower</td>
<td>1.96</td>
<td>66.24</td>
</tr>
<tr>
<td>Basic</td>
<td>1.96</td>
<td>66.24</td>
</tr>
<tr>
<td>Secondary</td>
<td>0.91</td>
<td>47.78</td>
</tr>
<tr>
<td>Higher</td>
<td>0.60</td>
<td>37.50</td>
</tr>
</tbody>
</table>

The results in the table definitely show a considerable difference in the probabilities of a prolonged unemployment of the persons who are out of work with different levels of education. What's peculiar in this case is that the impact of the educational level is polarized and is concentrated in two points - low and high level of
education. With the two low levels of education the probability of long-term unemployment of the persons out of work is 96% higher than the probability of short-term unemployment. The middle level of education does not have any substantial impact, since with it the probabilities of long-term and short-term unemployment are approximately equal. After the middle educational level there occurs a turn in the direction and the intensity of the impact - the probability of long-term unemployment of the persons out of work having higher education is 40% lower than the probability of short-term unemployment. This bipolar model of the influence of the educational level on the length of unemployment ceases functioning in an unstable economic environment affected by the disequilibrium between demand and supply on the labour market.

A multinomial logistic model of the relation between education and employment, the long-term and the short-term unemployment

The logistic models estimated above measure the chances of long-term or short-term unemployment of the persons who are unemployed, that is, they provide an answer to the question: what is the probability of the persons who have fallen in the category "unemployed" to be either long-term, or short-term unemployed, depending on the education that they have. If that question is expanded and applied to all economically active individuals constituting the supply on the labour market, it will be formulated thus: what is the probability of the persons constituting the workforce to be either employed, long-term or short-term unemployed, depending on the education that they have. Besides everything else, the response to this question would help us reach a logical explanation of the inadequacy of the logistic model (5), which describes as statistically insignificant the impact of education on the duration of the unemployment of the persons who are out of work in 2013. In order to solve the research question expanded in the abovementioned direction, there is used a multinomial logistic model (M-logit model) adapted to the specific subject area. The dependent variable in the model - "employment of the economically active persons" - is set as nominally scaled, with three possible outcomes for each monitored individual - employed, short-term unemployed or long-term unemployed. In accordance with the three possible outcomes, "π_1" in the model signifies the probability for employment, "π_2" - the probability for short-term unemployment, and "π_3" - the probability for long-term unemployment (\(\sum_{i=1}^{3} \pi_i = 1\)). The ratio \(\frac{\pi_2}{\pi_1}\) indicates the chance of
short-term unemployment (instead of employment), whereas the ratio \( \frac{\pi_3}{\pi_1} \) - the chance of long-term unemployment (instead of employment).

The *M-logit model* is developed consecutively on the basis of the data from 2008 and those from 2013. For each of the two years two variants of the model are designed - with regard to the chance of short-term unemployment (instead of employment), and with regard to the chance of long-term unemployment (instead of employment). The estimation of the parameters of the models for 2008 ends at the sixth iteration, as a result of which the models take the following concrete form:

\[
\ln \left( \frac{\pi_2}{\pi_1} \right) = -4.348 + 2.034c_1 + 1.156c_2 + 0.596c_3 \quad (6)
\]

\[
\ln \left( \frac{\pi_3}{\pi_1} \right) = -4.858 + 3.219c_1 + 2.341c_2 + 1.017c_3 \quad (7)
\]

The test characteristics for adequacy of the models and for significance of their parameters are the reason for them to be used for further analysis. Presented in terms of the chance of short-term and long-term unemployment, with the purpose of a clearer interpretation of their parameters, the models (6) and (7) take the following form:

\[
\frac{\pi_2}{\pi_1} = e^{-4.348 + 2.034c_1 + 1.156c_2 + 0.596c_3} \quad (8)
\]

\[
\frac{\pi_3}{\pi_1} = e^{-4.858 + 3.219c_1 + 2.341c_2 + 1.017c_3} \quad (9)
\]

The exponential parameter values of model (8) assess the chances of short-term unemployment (instead of employment) of the persons having primary, basic and secondary education, in relation to those of the persons having higher education. These chances are respectively 7.6, 3.2 and 1.8 times as high as the chance of short-term unemployment with the persons having higher education. The chances rise with the decrease in the level of education, the most significant increase being observed with the persons having primary and lower education. From the exponential parameter values of the second model - model (9), are obtained the chances of long-term unemployment (instead of employment) of the persons having primary, basic and
secondary education, as compared to the same chance with the persons having higher education. Here, also, is observed the pattern ascertained by the previous model - the chances of long-term unemployment rise with the decrease in the level of education, however, in comparison with the chances of short-term unemployment, they are considerably higher at all educational levels. With the persons having primary, basic and secondary education the chances of long-term unemployment (instead of employment) are respectively 25.0, 10.4 and 2.8 times as high as those with the persons having higher education.

The procedure of assessing the parameters of the M-logit models for 2013 ends at the sixth iteration as a result of which the models acquire the following form:

\[
\ln \left( \frac{\pi_2}{\pi_1} \right) = -3.596 + 2.352c_1 + 1.614c_2 + 0.727c_3
\]  \hspace{1cm} (10)

\[
\ln \left( \frac{\pi_3}{\pi_1} \right) = -3.313 + 2.772c_1 + 1.905c_2 + 0.862c_3
\]  \hspace{1cm} (11)

The test characteristics of the two models confirm their adequacy, as well as the statistical significance of their parameters. This is a good reason to continue the analysis with the exponential types of the models:

\[
\ln \left( \frac{\pi_2}{\pi_1} \right) = e^{-3.596 + 2.352c_1 + 1.614c_2 + 0.727c_3}
\]  \hspace{1cm} (12)

\[
\ln \left( \frac{\pi_3}{\pi_1} \right) = e^{-3.313 + 2.772c_1 + 1.905c_2 + 0.862c_3}
\]  \hspace{1cm} (13)

On the whole, the pattern established for 2008 with respect to the change in the chances of short-term and long-term unemployment (instead of employment) in the transition to a lower level of education, is preserved - the chances of both short-term, and long-term unemployment increase with the lower educational levels. These rather general findings, however, contain overtones which stand out clearly in the comparative analysis of the obtained results for the two analyzed years (Tables 2 and 3).
Table 2

Chance of short-term unemployment of the persons having levels of education that are different from those having higher education

<table>
<thead>
<tr>
<th>Level of completed education</th>
<th>Chance of short-term unemployment ($\pi_2/\pi_1$)</th>
<th>2008</th>
<th>2013</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary and lower</td>
<td></td>
<td>7,6</td>
<td>10,5</td>
<td>38,2</td>
</tr>
<tr>
<td>Basic</td>
<td></td>
<td>3,2</td>
<td>5,0</td>
<td>56,3</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td>1,8</td>
<td>2,1</td>
<td>16,7</td>
</tr>
</tbody>
</table>

Table 3

Chance of long-term unemployment of the persons having levels of education that are different from those having higher education

<table>
<thead>
<tr>
<th>Level of completed education</th>
<th>Chance of long-term unemployment ($\pi_3/\pi_1$)</th>
<th>2008</th>
<th>2013</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary and lower</td>
<td></td>
<td>25,0</td>
<td>16,0</td>
<td>-36,0</td>
</tr>
<tr>
<td>Basic</td>
<td></td>
<td>10,4</td>
<td>6,7</td>
<td>-35,6</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td>2,8</td>
<td>2,4</td>
<td>-14,3</td>
</tr>
</tbody>
</table>

In 2008 there exists a much greater differentiation between the chances of long-term and short-term unemployment with the low and - to a certain extent - with the middle level of education, in comparison with the higher educational level. The chances of long-term unemployment with the persons having primary and basic education are over 3 times as great as those of short-term unemployment. In 2013 the differences decrease to around 1.4 times greater chances of long-term unemployment with the persons having low level of education, whereas with those having secondary education the chances of long-term and short-term unemployment are almost equal. The results in Tables 1 and 2 show the diverging change in the two characteristics - the chances of long-term unemployment with the persons having different levels of education in relation to these with higher education, decrease, while those of short-term unemployment increase. This trend is observed in the highest degree with the two low educational levels, which is indicative of a decreasing impact of education on employment opportunities at the labour market in time of economic instability. The
convergence of the chances of long-term and short-term unemployment with the low educational levels and their equalization with the middle level of education results in an inadequacy of the estimated for 2013 logistic model of the relation between education and the duration of unemployment of the persons who are out of work.

Models (8), (9), (12) and (13) provide the opportunity to assess the probabilities of employment, short-term and long-term unemployment of the persons having different levels of education in the two years under study, and thus attain to further elements of the examined relations and expand the conclusions formulated above:

\[
\pi_1(2008) = \frac{1}{1 + e^{-4.348 + 2.034 c_1 + 1.156 c_2 + 0.596 c_3}}
\]

\[
\pi_2(2008) = \frac{e^{-4.348 + 2.034 c_1 + 1.156 c_2 + 0.596 c_3}}{1 + e^{-4.348 + 2.034 c_1 + 1.156 c_2 + 0.596 c_3}}
\]

\[
\pi_3(2008) = \frac{e^{-4.858 + 3.219 c_1 + 2.341 c_2 + 1.017 c_3}}{1 + e^{-4.858 + 3.219 c_1 + 2.341 c_2 + 1.017 c_3}}
\]

\[
\pi_1(2013) = \frac{1}{1 + e^{-3.596 + 2.352 c_1 + 1.614 c_2 + 0.727 c_3}}
\]

\[
\pi_2(2013) = \frac{e^{-3.596 + 2.352 c_1 + 1.614 c_2 + 0.727 c_3}}{1 + e^{-3.596 + 2.352 c_1 + 1.614 c_2 + 0.727 c_3}}
\]

\[
\pi_3(2013) = \frac{e^{-3.313 + 2.772 c_1 + 1.905 c_2 + 0.862 c_3}}{1 + e^{-3.313 + 2.772 c_1 + 1.905 c_2 + 0.862 c_3}}
\]

The results obtained by means of the models presented above are given in Table 4.
Table 4

**Chance of short-term and long-term unemployment of the economically active persons having different levels of education (%)**

<table>
<thead>
<tr>
<th>Level of completed education</th>
<th>Chance of short-term unemployment instead of employment ($\pi_2/\pi_1$)</th>
<th>Chance of long-term unemployment instead of employment ($\pi_3/\pi_1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2008</td>
<td>2013</td>
</tr>
<tr>
<td>Primary and lower</td>
<td>9.9</td>
<td>28.8</td>
</tr>
<tr>
<td>Basic</td>
<td>4.1</td>
<td>13.8</td>
</tr>
<tr>
<td>Secondary</td>
<td>2.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Higher</td>
<td>1.3</td>
<td>2.7</td>
</tr>
</tbody>
</table>

The results presented in Table 3 show that in 2008 the chances of long-term unemployment of the persons having low level of education are twice as great as their chances of short-term unemployment (instead of employment). The rise in the level of education leads to the dwindling of the difference and to a lower chance of long-term unemployment with the persons having higher education. The changed situation on the labour market in 2013 affects in a different manner the opportunities for career realization of the persons having different levels of education. The chances of long-term unemployment increase at each of the educational degrees, but with the persons having low education they remain, just like in 2008, approximately twice as great as their chances of short-term unemployment. Things look differently with the persons having secondary and higher education. If in 2008 the chance of long-term unemployment with them is respectively almost equal to, or lower than their chance of short-term unemployment, in 2013 the chance of long-term unemployment with both educational levels is about 1.5 times as great as that of short-term unemployment. This fact is indicative of a much more intensive increase in the chance of long-term unemployment with the persons having secondary and higher education in comparison with the persons having low educational levels. With the low educational levels the chance of long-term unemployment increases threefold in 2013, whereas with the persons having middle and high educational degrees the increase is 4 and 5 times, respectively (Table 5).
Table 5

Change in the chance of short-term and long-term unemployment of the economically active persons having different levels of education in 2013 in relation to 2008 (%)

<table>
<thead>
<tr>
<th>Level of completed education</th>
<th>Increase in the chance of short-term unemployment instead of employment ($\pi_2/\pi_1$)</th>
<th>Increase in the chance of long-term unemployment instead of employment ($\pi_3/\pi_1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary and lower</td>
<td>191</td>
<td>200</td>
</tr>
<tr>
<td>Basic</td>
<td>235</td>
<td>203</td>
</tr>
<tr>
<td>Secondary</td>
<td>142</td>
<td>303</td>
</tr>
<tr>
<td>High</td>
<td>113</td>
<td>372</td>
</tr>
</tbody>
</table>

Conclusion

The results of the conducted study of the relation between education and the duration of the unemployment in Republic of Bulgaria, under the conditions of an imbalanced labour market, gives us reason to make the following generalized conclusions:

1. Under conditions of economic stability there is observed a bipolar model of the impact of education on the duration of unemployment of the persons who are out of work - a much higher probability for prolonged unemployment of the unemployed persons having low education, approximately equal probabilities with the persons having secondary education, and a considerably lower probability for prolonged unemployment with the unemployed persons having higher education. This model of the impact of the educational level on the duration of unemployment ceases to function in an unstable economic environment. The existence of a disequilibrium between the demand and supply on the labour market obliterates the role of the higher educational level for reducing the duration of the unemployment of the persons who are out of work.

2. Both under conditions of a stable labour market, and under an imbalanced labour market the chances of both short-term, and long-term unemployment are smaller for the persons having a higher level of education. Considerably different, however, is the intensity of the change in these chances upon a change in the parameters of the economic environment, in which the labour market functions. Under unfavourably changed economic conditions the chances of long-term unemployment increase at
each one of the educational levels, but with the persons having low education the intensity of this increase is much lower in comparison with the intensity of the increase with the persons having secondary and higher education. This means that with the persons having low education the effect of the economic instability is expressed only in an increase in the rate of the long-term and the short-term unemployment - an increase of an approximately equal degree, which does not lead to a change in the ratio of the chances of these persons to be long-term or short-term unemployed. Such a change, however, is found with the persons having secondary and higher education, and it is in the direction of an intensive increase in their chance of long-term unemployment under conditions of an unstable labour market.

3. The generalizations made above lead to the conclusion of a decreasing impact of education on the possibilities for reducing the duration of unemployment in time of economic instability. In that sense there comes to the fore the need to reconsider the policy on the labour market, which - in periods of a destabilized labour market - is directed predominantly at the poorly-educated persons. Putting the persons having a higher level of education in the focus of this policy would affect not only the parameters of the labour market, but also the overall condition of the economic environment in which it functions.

End Notes

1. There have been used data on the economically active persons aged 15-64.
2. Persons who have been out of work for a period exceeding one year are considered as long-term unemployed (AN).
3. There have been used data on the economically active persons aged 15-64.

References


DEVELOPING AN ALGORITHM FOR GENERATING COMPUTERIZED TEST COMBINATIONS

Ivan KUYUMDZHIEV

Abstract

This article focuses on computerized testing as one of the most effective methods of assessment in higher education. The study demonstrates problems of generating tests with random questions using computers. Proposed algorithm overcomes these difficulties taking into account predefined complexity of each question used in the test. Multiple tests of the productivity of the algorithm show the results of different scenarios and help assess its quality. The reason these findings are important is that they demonstrate an effective method for the computerized creation of tests that could be described as preadaptive.

Keywords: Multiple Choice Testing, Assessment in Higher Education, Computerized Adaptive Tests.

In a crisis, more than ever before, it is necessary to improve the quality of higher education and raise the effectiveness of universities. Assessing students' knowledge is an essential part of the process of education. The assessment process involves several stakeholders among which students and lecturers come first. Students get an understanding of whether the knowledge and skills they have acquired are clearly visible and measurable at a certain point of time. For the lecturer this turns into a condition and mechanism for adjusting their own work in terms of educational content – whether particular topics are fully comprehended and utilized, which ones present more than the usual level of difficulty for the students, etc. (Desev et al, 1977, p. 446).

Another participant in the process of assessment are the higher education institutions. Checking students' level of knowledge (incl. admission exams, continuous assessment, term grades, state examinations) consumes a huge amount of resource – lecture halls occupancy and lecturers teaching load, printed teaching materials, etc., which means that even a slight improvement of efficiency would result in considerable economies on a global scale.

JEL 1210, C830, C880

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Stakeholders also include legislators, employers and parents (Patrick et al., 2008). The government partially subsidizes institutions of higher education and sets various criteria for accreditation which also contain requirements on the effectiveness of assessment and the use of modern methods to achieve this (NAOA, 2011). Employers, on the other hand, need to feel confident that they are hiring well-prepared specialists, while parents, who usually pay for their offspring's education, view assessment as a measure of their progress.

Following from the above, raising the effectiveness of testing will result in the positive attitude of learners, employers and parents on the one hand, and lecturers, university governing bodies and government institutions on the other. Taking into consideration this fact, this article aims to develop and test the effectiveness of a module of a test system, which in itself represents an algorithm for generating test combinations.

1. Test format of examinations and problems with a computer-generated test combination under certain criteria

Using tests is the best known form of examination. Varieties can be defined based on the type of questions (true/false, short answer, fill in the blanks, matching, multiple choice questions (Gyurova, V. et al., 2006, p. 260)) or the method of scoring (scoring of correct answers only, withdrawal of points for wrong answers, bonuses for omitted answers, scoring for partial knowledge, questions with more than one correct answer, withdrawal of points for omitted answers (Lesage et al, 2013). A great deal of research has been carried out in search of an answer to the question "which is the most exact method of evaluation" and "which is the best test format", all reaching multidirectional results (Kastner and Stangla, 2011, Ventouras et al., 2010), but despite the scientific community arguments concerning the complexity of various types of test and the efficiency of evaluation methods, it is beyond doubt that performing computer-generated multiple-choice tests can potentially and to a large degree eliminate the subjective factor in assessment. The degree of objectivity depends on which part of the process is automated. With partially automated tests the choice of questions to include in the tests and/or assessing test scores is performed by a human. In order to minimize the subjective factor it is also necessary for both test generation and scoring to be automated.

The developed algorithm for generating computerized tests is part of a comprehensive testing system which reduces lecturers' involvement in the design of the examination to inputting a bank of test questions and choosing the criteria for test generation. For every question lecturers assign a weight (in the 1 to 5 range), which
allows for a precise calibration of the overall difficulty of the test. After the end of the examination, the system generates a reference sheet containing information on which questions were most often given wrong answers, and which were most often answered correctly, which in turn can be used as a foundation for correcting the questions' weights. After the complexity of each question is identified, the system will contain a reasonably varied database to be used for adding options in order to generate adaptive tests. With these tests a level of complexity is assigned to each question and the next question in the text depends on the answers to previous ones (Eskenasi et al., 1993). In a certain variant of adaptive test, if the learner answers correctly, the next question will be more difficult; should the answer be wrong, the next question can be less difficult. According to some researchers (Wainer et al., 2014) adaptive testing provides exact measurement of student knowledge, as students come with varying levels of preparedness. According to the same study the classical multiple-choice test assesses only the students with a medium level of knowledge and definitely does not do a favour to those of higher or lower levels of knowledge.

Despite the said advantages of computer-generated testing, the reduced expert involvement throughout the stages of creating the variants and their assessment suggests the development of a dedicated algorithm that is flexible enough to allow for test generation under preliminary set criteria. In order for a quality module to be created, the needs and requirements of each type of user must be studied.

At a conceptual level the work of the test-generating algorithm can be described in fig.1, where the following users of its functions can be identified – lecturers, system administrators, students/candidate-students, computer programmers.
Fig. 1. Interaction with the test-generating algorithm

Test parameters are set by lecturers and are input by system administrators. The duration and complexity (the sum total of the weights of the questions included) of the test, the students for which the test is active, as well as the time period when the test is accessible are characteristics of every test generated. Apart from the above, the following variants are available:

A) test generation according to a set total number of questions;
B) test generation according to a set total number of questions from a defined range of topics;
B) test generation by selecting a certain number of questions on each topic.

Needs analysis makes it clear that from the point of view of lecturers the system should generate a test containing a random selection of questions that meet the above criteria.

The next participants in the test-generating process are system administrators. They are the users who input the lecturer-set requirements and monitor the successful execution of the algorithm. As basic parameters of quality work of the system administrators identify the quick execution of the set requirements, as well as the high level of system dialog – with incorrect input, messages show not only the reason, but also the way to eliminate the problem.
After the test has been generated, it is accessible to the examined students for the stipulated time period. Students are passive users of the algorithm – they do not take part in its execution and their requirements for a fair distribution of questions depend on the criteria that have been set by the lecturer during test generation.

The test generating algorithm is part of the overall system of the testing centre and as such it interacts with other modules of this system, as the modules for reshuffling questions and answers, which in turn are a component of the test visualization module, etc. The requirements set by other programmers include fast response and a unified, predictable output from the execution, which can be used in the dependent modules.

A major problem in system development is the creation of an algorithm which should function efficiently with both small and large databases. The main factors affecting performance are: the number of questions in the test, the number of questions in the database that meet the weight requirements. The number of the latter largely depends on the interval of complexity of the end result test in setting the criteria – the larger the interval, the greater the number of questions that are able to meet the set criterion. From this standpoint, several combinations are possible in order to distribute the questions from a database:

k1) the database contains many questions with various weights and the user requires the creation of a test with a limited number of questions. For example, a choice of 10 questions out of 200 questions available in the database and grouped into 10 topics, with 20 questions on each topic;

k2) the database contains many questions, the user requires a large test, but the number of questions in the test is, again, a small percentage of what is available in the database. For example, generating a 100-question test where the database includes 10 topics with 70 questions on each topic;

k3) the number of database questions whose weights meet the users’ requirements is close to the number of questions necessary to generate the test;

K3.1) generating a large test of 150 questions where 20 topics with 10 questions on each topic are available in the database;

K3.2) generating a short test of 15 questions, of the type used for current assessment, where the database is small and only contains 10 topics with 2 questions on each topic.

Analysis of the above mentioned examples puts forward the following major problems:
1. A markedly uneven distribution of questions. If variant A) for test generation is used, there is a good chance that the random choice of questions will result in a distinctly uneven distribution of questions and topics – incl. the probability of the test covering questions on one topic only, and/or certain topics not being covered at all.

Let us suppose we have a bank of $u$ number of test topics, with each topic containing $v$ number of questions and let us randomly retrieve $w$ number of them. As the total number of questions equals $u \cdot v$, the number of all possible combinations for drawing the questions is

$$n = \binom{u \cdot v}{w} = \frac{(u \cdot v)!}{w!(u \cdot v - w)!}$$

(1)

Let us now calculate the probability of the questions drawn to be distributed in exactly $k$ number of topics. Evidently, $k \leq \min(u, v)$.

We number the topics in random order from 1 to $u$. Then every possible distribution of questions within the separate topics is described by a vector with dimensions $u$ topics with $k$ strictly positive components and $u - k$ zero components:

$$X = (x_1, x_2, \ldots, x_u),$$

(2)

for which the following conditions are fulfilled:

$$\sum_{i=1}^{u} x_i = w \text{ и } x_i \leq v \ (i = 1 \ldots u).$$

If vector components (2) are arranged in descending order, then the vector appears as

$$X^*_{k,s} = (x_1, x_2, \ldots, x_k, 0, \ldots, 0), \text{ като } x_1 \geq x_2 \geq \ldots \geq x_k \geq 1,$$

(3)

where $S = \{X^*_{s}\}$ is a finite set of vectors.

The set of vectors (2) includes all the possible permutations from the elements of all vectors (3). As these are permutations with repetitions, their number can be found using the formula

$$\bar{p}_{k,s} = \frac{u!}{(u - k)!k_{s,1}!k_{s,2}!\ldots k_{s,t}!},$$

(4)

where:
- $(u - k)$ - number of zero elements of (4);
- \( k_{s,j}, \ (j = 1...t) \) - number of elements equal to 1, 2, ..., \( t \), \( \sum_{j=1}^{t} k_{s,j} = w \).

The number of the different variants for retrieving the questions on the topics for each vector (3) will equal

\[
\left[ \prod_{i=1}^{u} \frac{v!}{x_i! (v - x_i)!} \right]_{s \in S} \tag{5}
\]

Vectors (3) are random partitions of the number \( w \) into exactly \( k \) positive numbers. Their number is defined by recurrence equations (Hall, 1970). Algorithms for generating partitioning are provided by (Knuth, 2013).

Having in mind (4) and (5), then the number of all possible distributions of the \( w \) question into exactly \( k \) test sections is

\[
m_k = \sum_{s \in S} \frac{u!}{(u-k)! k_{s,1} k_{s,2} \ldots k_{s,t}!} \left[ \prod_{i=1}^{u} \binom{v^i}{C_x} \right]_s \tag{6}
\]

Then the probability of the drawn questions being distributed in exactly \( k \) topics will be

\[
P_k = \frac{m_k}{n} \tag{7}
\]

Suppose, for example, we have a bank of 10 topics and each topic contains 20 test questions. The test contains 10 questions which are randomly retrieved from the whole set. We shall calculate the probability of grouping the questions into 7 topics. Vectors \( X_{s \in S}^* \) are:

\[
X_{7,1}^* = (4,1,1,1,1,1,0,0,0); \\
X_{7,2}^* = (3,2,1,1,1,1,0,0,0); \\
X_{7,3}^* = (2,2,2,1,1,1,0,0,0).
\]

Using (1), (6) and (7), we define

\[
n = 22451004309013280, \\
m_7 = 836304000000000,
\]

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\[ P_7 \approx 0.37250182 \, 151729 \, . \]

Similarly we define (table1)

### Table 1

<table>
<thead>
<tr>
<th>Number of topics from which questions are selected ((k))</th>
<th>Number of implementations ((m_k))</th>
<th>Probability ((P_k))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 topic</td>
<td>1847560</td>
<td>0.000000000008229</td>
</tr>
<tr>
<td>2 topics</td>
<td>65439360720</td>
<td>0.00000291476318</td>
</tr>
<tr>
<td>3 topics</td>
<td>8742192030000</td>
<td>0.00038938979787</td>
</tr>
<tr>
<td>4 topics</td>
<td>283502570400000</td>
<td>0.01262750891398</td>
</tr>
<tr>
<td>5 topics</td>
<td>2475475002000000</td>
<td>0.11026121450639</td>
</tr>
<tr>
<td>6 topics</td>
<td>7435792728000000</td>
<td>0.33120089532096</td>
</tr>
<tr>
<td>7 topics</td>
<td>83630400000000000</td>
<td>0.37250182151729</td>
</tr>
<tr>
<td>8 topics</td>
<td>34364160000000000</td>
<td>0.15306290768562</td>
</tr>
<tr>
<td>9 topics</td>
<td>437760000000000000</td>
<td>0.01949845957778</td>
</tr>
<tr>
<td>10 topics</td>
<td>102400000000000000</td>
<td>0.00045610431760</td>
</tr>
</tbody>
</table>

Results in the table show that on average 33 out of 100 generated tests would include questions from 6 topics only, which would exclude 40% of the studied material. Despite the slim probability, it is even possible for all questions to be selected from one and the same topic. This brings us to the conclusion that it is necessary to apply a mechanism which regulates the number of chosen questions for each topic using variant A) for test generation.

2. Impossibility to cover all combinations. The total number of possible combinations grows in parallel with the size of the database. Calculating each combination would lead to a huge waste of computational resources and time. The results of calculations for a number of combinations for the examples mentioned are shown in table 2\(^1\).
Number of possible tests

<table>
<thead>
<tr>
<th>Database and test</th>
<th>Number of combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test of 10 questions chosen out of 200 questions</td>
<td>$2^{54.31}$</td>
</tr>
<tr>
<td>Test of 100 questions chosen out of 700 questions</td>
<td>$2^{409.63}$</td>
</tr>
<tr>
<td>Test of 150 questions chosen out of 200</td>
<td>$2^{158.31}$</td>
</tr>
<tr>
<td>Test of 15 questions chosen out of 20</td>
<td>15504</td>
</tr>
</tbody>
</table>

While generating each combination, a check should be made on whether the sum of the weights of the questions in the combination matches the overall requirement for the difficulty of the test. The search for correct combinations can be compared to decoding an encrypted message. Thus for example for breaking the (once considered unbreakable) hash encryption algorithm SHA-1 $2^{69}$ operations are enough (Schneier, 2005).

Despite the growing capacity of computer hardware, performing such a volume of calculations is difficult to achieve. A Chinese supercomputer developed in 2013 performs 33.86 trillion operations a second. If the calculating power of this computer were to be used the time it took to check the first three combinations would be as follows:

<table>
<thead>
<tr>
<th>Database and test</th>
<th>Time to process all combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test of 10 questions chosen out of 200 questions</td>
<td>11.05 minutes</td>
</tr>
<tr>
<td>Test of 100 questions chosen out of 700 questions</td>
<td>$2^{371.78}$ years</td>
</tr>
<tr>
<td>Test of 150 questions chosen out of 200</td>
<td>$2^{126.46}$ years</td>
</tr>
</tbody>
</table>

The impossibility of looping through all combinations creates a problem in cases where a very small number of combinations meet the set requirements.

2. Describing and testing an algorithm for generating a computerized test combination

In an attempt to solve the said problems there has been developed an algorithm with the following structure (fig. 2)
Fig. 2. Algorithm for test generation

The probability of selected questions being concentrated in certain topics is eliminated by generating a combination of a random number of questions for each module, with the minimum being 1 (step 1). Due to the nature of random choice it is possible that the database does not include questions with suitable weights to meet the user's requirements for the overall complexity of the test. For example, if the topic only contains questions with the weight of 3, and the user demands a maximum complexity test, i.e. only with weight 5 questions. Nevertheless, no exclusion has been made of combinations that cannot be satisfied, as that corresponds with the issue of the impossibility to cover all variants.

In order to improve fast response and retain the probability for a random choice of test, the number of operations is reduced to whichever is less: either 200 000 or the total number of combinations*3 (step 6). As it was mentioned above, there is a good chance that the randomly chosen set of a number of questions does not contain a combination to match the requirements. On the other hand, it is possible for such a combination to exist, but not to be found even after 200 000 reshuffles. For this reason a recursion is added to the algorithm (step 7) and a reciprocal reshuffling quotient (RRQ) - N. RRQ stipulates what percentage of questions whose weights are closest to average should be chosen before reshuffling. For example, the requirement is to create a test of medium-level complexity and thus choose medium-level of complexity questions. At the beginning of the execution this quotient is zero, and with each following recursion it grows by 10%, so that execution time decreases, because the more questions are chosen based on their weights, the fewer possible combinations remain for random choice.
Despite the nearly 2 million operations, it is still possible not to find the right set of questions to meet the requirements. For this reason, a function has been created (step 8) for targeted search of questions with suitable complexity. Search mechanisms for certain questions, however, to some degree contradict the requirement for random choice, but are the only instrument in cases where the overall number of combinations is impossible to loop through.

Reports on the functioning of the system show that over 1000 tests were carried out in the last year. Test generation takes on average 0.0002 seconds, and maximum execution time is close to 0.001 seconds, which demonstrates a reasonably fast response of the algorithm. Despite the relatively large number of tests there has not been a single entrance into recursion. These findings result from the state of the database and the test requirements. At present there is a very small percentage of questions with a weight other than 3, while the requests for test generation demand a large interval of overall test complexity. Under such conditions every randomly drawn combination would match the set parameters.

The above mentioned results are not enough to determine the efficiency of the proposed algorithm and for this reason a test module has been created for an in-depth study of the capacity of the algorithm in various situations. The following hardware configuration has been used - Intel Core i3-3130M CPU @ 2.60GHz, HDD - HGST 7200RPM SATA-III 500GB, RAM - 4 GB DDR3-1600(800MHz) SDRAM. Test execution software includes OS Windows 7 Pro 32 bit with SP1, PHP 5.5.6 language and DBMS MySQL Community Server 5.6.14.

The basic parameters of the test module have been set so as to match the 4 cases discussed above, namely:

1) generating a test of 10 questions out of 200 questions available in the database;
2) generating a test of 100 questions out of 700 available in the database;
3.1) generating a test of 150 questions out of 200 available in the database;
3.2) generating a test of 15 questions out of 20 available in the database.

The questions are evenly distributed by topic. To check the system efficiency with different weight quotients, five sample databases with different quotients are created. Question complexity in these databases can be any number between - 1 and 4; 2 and 5; 1 and 5; 2 and 4; all questions have type 3 complexity.

For each combination (40 altogether) of the said types of test and weighted databases a condition is set for generating 4000 tests within a time frame of max. 10 minutes. In order to simulate various requirements for the overall complexity of the test, each batch of 20 tests receives requirements from the widest possible range (with
variant 1 overall complexity should be between 10 and 50) to the most limited one possible, with the increase of the upper limit and lowering the threshold taking place at each 2%. Thus each test that was first generated out of the batch of 20 has the easiest requirements, and every 20th test has the most difficult ones.

3. Results and conclusions

The conducted tests demonstrate that the average time for a single test generation is 0.110 seconds with 52118 tests generated.

Table 4

Results from the tests performed

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Question weights in database between</th>
<th>Average number of iter.</th>
<th>Max. number of iter.</th>
<th>Average gen. time (sec)</th>
<th>Max. gen. time (sec)</th>
<th>Total numb. tests</th>
<th>Number exec. of targeted choice</th>
<th>Number cases of entr. in recursion</th>
<th>Average number of recursions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2)</td>
<td>1-4</td>
<td>1.20</td>
<td>8</td>
<td>0.000</td>
<td>0.016</td>
<td>760</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.1)</td>
<td>1-4</td>
<td>70.27</td>
<td>987</td>
<td>0.660</td>
<td>199.475</td>
<td>779</td>
<td>-</td>
<td>10</td>
<td>0.0231</td>
</tr>
<tr>
<td>1)</td>
<td>1-4</td>
<td>2.47</td>
<td>9</td>
<td>0.0004</td>
<td>0.016</td>
<td>780</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2)</td>
<td>1-4</td>
<td>4.35</td>
<td>9</td>
<td>0.002</td>
<td>0.312</td>
<td>780</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.2)</td>
<td>1-5</td>
<td>1.02</td>
<td>9</td>
<td>0.003</td>
<td>7.300</td>
<td>4000</td>
<td>2</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>3.1)</td>
<td>1-5</td>
<td>1.00</td>
<td>2</td>
<td>0.001</td>
<td>0.016</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1)</td>
<td>1-5</td>
<td>1.46</td>
<td>9</td>
<td>0.0003</td>
<td>0.016</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2)</td>
<td>1-5</td>
<td>1.00</td>
<td>1</td>
<td>0.001</td>
<td>0.016</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.2)</td>
<td>2-4</td>
<td>1.00</td>
<td>1</td>
<td>0.000</td>
<td>0.016</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.1)</td>
<td>2-4</td>
<td>1.00</td>
<td>1</td>
<td>0.001</td>
<td>0.016</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1)</td>
<td>2-4</td>
<td>1.17</td>
<td>9</td>
<td>0.0002</td>
<td>0.016</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2)</td>
<td>2-4</td>
<td>1.00</td>
<td>1</td>
<td>0.001</td>
<td>0.027</td>
<td>4000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.2)</td>
<td>2-5</td>
<td>1.04</td>
<td>4</td>
<td>0.0002</td>
<td>0.016</td>
<td>240</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3.1)</td>
<td>2-5</td>
<td>32.64</td>
<td>9</td>
<td>1.523</td>
<td>226.347</td>
<td>259</td>
<td>1</td>
<td>5</td>
<td>0.06</td>
</tr>
<tr>
<td>1)</td>
<td>2-5</td>
<td>2.39</td>
<td>9</td>
<td>0.0004</td>
<td>0.016</td>
<td>260</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2)</td>
<td>2-5</td>
<td>1.43</td>
<td>9</td>
<td>0.001</td>
<td>0.016</td>
<td>260</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
The highest average generation time (0.437 sec.) is spent on a test of 150 questions chosen from a database of 20 topics with 10 questions for each topic, and the lowest generation time (0.0003 sec.) went on a test of 10 questions with 10 topics, 20 questions on each topic. Results show that test generation time is directly related to the number of iterations and the number of recursions, and they, in turn depend not only on the size of the database and the size of the required test, but also on the correspondence between the overall complexity of the test and the weights of the individual questions in the database. The longest average execution time was spent on tests where the database questions have weights between 2 and 5 or between 1 and 4 i.e. databases of lower or higher than average complexity. The fifth database, comprised from weight 3 questions only, corresponds to the state of the database used in practice and proves the statement that execution speed and the small number of iterations are the result of setting wide search criteria and lack of diversity in the complexity of questions.

Results show that the test generation algorithm fulfils the set requirements. It runs at a satisfactory speed with both large and small databases. Conditions for improving its robust performance are as follows: inputting a set of questions of diverse complexity and creating tests with up to several dozen questions.

The use of recursion delays script execution but leads to the generation of a test with absolutely randomly chosen questions. As it was said before, despite the large number of reshuffles and recursions, in certain cases it is necessary to apply the function for targeted search of questions with suitable weights – this happened on three occasions out of over 52,000 cases in the tests we performed.

The use of the developed algorithm facilitates the work of the Test Center at Varna EU. Computer-generated tests from the developed module reduce the subjective factor and contain a fair and random distribution of questions by topic. At the same time, they raise the economic efficiency of carrying out examinations, as they reduce:

- the cost of photocopying a test;
- the time spent on performing the test;
- the time it takes to check and assess the results. The need of using software developed by an external organization is eliminated and an opportunity is cre-
ated for further development of the product – implementation of adaptive test system. Another prospect for the test center can be the potential for performing certificate exams for external organizations. The smooth performance of the algorithm over the last 12 months proves that it fulfills the requirements set by the users. Applying the algorithm for the purposes of admission exams and the conducted tests demonstrate its ability to also work with larger databases without a noticeable effect on execution time.

I wish to express my deep gratitude to the colleagues, without whom this article and the software it discusses would not exist: Georgi Zelenkov, Deyan Mihaylov, Milen Marinov, Petar Dimitrov.

Acknowledgements: Georgi Zelenkov, Deyan Mihaylov, Milen Marinov, Petar Dimitrov

End Notes

1. Calculated using the formula \( c_n^k = \frac{v_n^k}{p_k} \)

References


OPTIMIZATION OF MARITIME TRANSPORT MANAGEMENT

Radan MIRYANOV\textsuperscript{1}

\begin{tabular}{|l|l|}
\hline
JEL – C61 & Abstract \\
\hline
\multicolumn{1}{|l|}{Keywords:} & In the present paper different methods and strategies for optimizing the maritime shipping management are revealed. The beginning of the article is dedicated to some opportunities for constructing the mathematical model of the problem. Then an approach to determining its solution is presented, observing all the positive points concerning its level of difficulty with different aspects of dynamic optimizing and duality included. \\
\hline
\end{tabular}

Maritime transport is an essential component of the global logistics system as its role is not only to effect the physical movement of goods but also to provide a far broader range of logistics services. It can be defined as a key logistics function related to the relocation of goods by certain means of transport, such as the various types of ships in the supply chain and in particular, the loading, shipping and unloading of the goods from and to the respective ports (Estache and Trujillo, 2009). The advantages of this mode of transport lie in the high carriage capacity and the virtually unlimited carrying capacity allowing large-scale intercontinental carriage of goods, and especially in the extremely low cost (Ducruet and Notteboom, 2011). From the above it becomes clear that this mode of transport connects quite remote destinations within the logistics system of the maritime transport and plays a key role in connecting many of the participants in the logistics processes (Bowersox, Closs and Cooper, 2002): manufacturers, suppliers, customers, consumers, warehouses, etc. If maritime transport is not included and above all integrated into the logistics processes, this will inevitably incur additional costs, unwanted delays, increased risk of accidents or other disturbances in the logistics processes (Caramia and Guerriero, 2009). In this context, maritime transport is to a great extent responsible for the carriage of goods in a way that is to the highest degree synchronized with the other components of the logistics process (Fransoo and Lee, 2011).

The enormous importance of maritime transport can be inferred from the ever increasing rate of world trade realized by seaborne shipments (Figure 1). The figure

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below shows clearly the essential role of maritime transport in the context of World Trade, GDP and Industrial Production Index.

**Figure 1. Comparison between the rates of world trade, seaborne trade, GDP and IPI**

The graphs in Figure 1 show that after the recovery of the global economy from the recession, seaborne shipments have grown steadily, especially over recent years. In this regard it should be noted that transport operators are increasingly faced with the problem of how to manage the flow of goods along the various routes for maximum benefit (Wilmsmeier and Hoffmann, 2008), i.e. to minimize the prime costs and expenses for freight transportation. In this connection, the present study aims to construct an idealized economic-mathematical model for optimization of the costs incurred by transport operators for managing the different route lines: a solution with both regional and global application. One of the important issues to be resolved by such an operator is to decide on how many and what ship types of the available fleet
to use, to operate different routes in the best possible way. This requires not only meeting the needs of the operator’s customers, but also minimizing the overall costs of freight transportation along the respective routes.

Therefore we think that the economic-mathematical model proposed in this study aims to help maritime transport operators solve this problem. From a practical point of view, this problem can be solved most easily by using online computational software (for example www.zweigmedia.com and www.wolframalpha.com), which nowadays is a convenient and highly recommended approach.

Along with the mathematical formalization of the problem, an attempt will be made to propose suitable approaches and corresponding methods to find the optimal plans for the relevant mathematical models. Here we can argue that a certain mathematical model may be perfect in terms of the formalization it achieves, but if there is no method to make it feasible, it will remain just a human creation with no practical value.

As is well known (Atanasov, 2015), the initial stage of modeling is formulation and analysis of the economic problem at hand. Let us assume that a maritime operator can operate \( m \) number of routes, and let the given future period be sufficiently foreseeable so that the company has complete clarity regarding the quantity of loads to be transported. Principally, this assumption does not impair the generality of the problem discussed, given that present-day operators operate under clear contractual relationships with relatively long durations, and very rarely, only in certain exceptional circumstances, make emergency decisions (Fremont, 2009). Under these conditions, the operator must decide how many and what type of vessels (e.g. container ships) to allocate to each route, in order to simultaneously achieve customer satisfaction and minimize the cost of freight transportation.

Let us further assume that the container ships available to the operator can be subdivided into \( n \) number of types. As already mentioned, in terms of maritime practice it is justified to group the vessels by tonnage and capacity (Slack, 2011). Furthermore, we should take into account the fact that not every type of container ships can be allocated to each of the operated routes, as some of the destination ports do not allow mooring such types of vessels (e.g. draft, room for maneuver, etc.).

For the purpose of constructing the mathematical model of the problem we will introduce the following symbols:

\[
c_{ij}: \text{the expenses for a complete run of a container ship of type } j \text{ along route } i, \quad i = 1, m, \quad j = 1, n;\]
\( d_{ij} \): the number of days a container ship of type \( j \) along route \( i \) waits lying at anchor at a roadstead, \( i = 1, m, \ j = 1, n \);

\( r_j \): the expenses for a one-day wait at roadstead of a container ship of type \( j \), \( j = 1, n \);

\( f_{ij} \): the number of container ships of type \( j \) whose technical characteristics allow completion of route \( i, \ i = 1, m, \ j = 1, n \);

\( \lambda_{ij} \): the container carrying capacity of a ship of type \( j \) on route \( i, \ i = 1, m, \ j = 1, n \);

\( a_i \): the total number of containers to be shipped along route \( i, \ i = 1, m \);

\( b_j \): the number of container ships of type \( j \) available to the operator, \( j = 1, n \).

It should be noted, that the above parameters are governed by the following mathematical correlation:

\[
\min_{ij} \left\{ f_{ij} \right\} = \min \left\{ \left[ \frac{a_i}{\lambda_{ij}} \right], b_j \right\},
\]

where \( \left[ \frac{a_i}{\lambda_{ij}} \right] \), constitutes the entire part of \( \frac{a_i}{\lambda_{ij}} \).

To complete the economic-mathematical model of the problem at hand we will further introduce the variables \( x_{ij} \), denoting the unknown number of container ships of type \( j \) to be allocated on route \( i, \ (i = 1, m, \ j = 1, n) \). The target function, whose minimum value is the object to be found, includes the total cost of container transportation to the end users. These costs are represented by two items: the costs incurred in the operation of the container ships during transport, and the costs of lying at roadstead. According to the symbols adopted, the first item is represented as follows:

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij},
\]

while the second item, i.e. the costs for lying at roadstead take the following mathematical expression:
When the above two groups of costs are added together, the optimality criterion, whose minimum value will be sought, will have the following expression:

\[ Z(X) = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} + \sum_{i=1}^{m} \sum_{j=1}^{n} r_j d_{ij} x_{ij}. \]

What could be the possible restrictions that would give rise to certain constraints? First, the containers scheduled for shipping must be transported, i.e. they must be loaded on container ships with respective capacity in order to be transported along the relevant routes. This requirement can be formalized by the following constraint:

\[ \sum_{j=1}^{n} \lambda_{ij} x_{ij} \leq a_i, (i=1,m). \]

Furthermore, it is clear that the container ships of each type to be allocated to the respective routes must be consistent with those that the company actually owns and/or uses. Hence the next constraint:

\[ \sum_{i=1}^{m} x_{ij} = b_j, (j=1,n). \]

On the other hand, the technical capabilities of the individual container ships to carry goods along the respective routes should also be taken into account, i.e.

\[ 0 \leq x_{ij} \leq f_{ij}, (i=1,m; j=1,n). \]

Moreover, besides this constraint, the variables \( x_{ij} \) should be positive natural numbers or zeros, given the fact that the object sought is a number of indivisible units such as container ships.

The above brings us to the following economic-mathematical model:

Find the minimum value of the linear form

\[ Z(X) = \sum_{i=1}^{m} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij}) x_{ij} \]  \hspace{1cm} (1)

subject to the following constraints:

\[ \sum_{j=1}^{n} \lambda_{ij} x_{ij} \leq a_i, (i=1,m) \]  \hspace{1cm} (2)
\[
\sum_{i=1}^{m} x_{ij} = b_j, \ (j = 1, \ldots, n) \\
0 \leq x_{ij} \leq f_{ij}, \ (i = 1, m; \ j = 1, n), \ x_{ij} \text{ are integers.}
\]

The model (1)–(4) may be brought under the class of operational problems related to allocation of resources, i.e. in terms of its structure this model is comparable to the general allocation problem, with the exception of constraint (4) (Atanasov, 2010). The existing constraints (4) and the requirement that the variables be integers makes it considerably harder to solve model (1)–(4). In this regard, the following is an attempt to propose a suitable approach and a corresponding method of finding the optimal plan for the model. To this aim, we shall first formulate and subsequently use another problem, provisorily designated as an evaluation problem. This evaluation problem will be formulated for the general case of the problem of integer optimization (Atanasov et al., 2010):

\[
Z_0 = \max_{X \in K} Z(X),
\]

where \( X = (x_1, x_2, \ldots, x_n) \) is \( n \)–dimensional vector, and \( K \) is an area of permissible solutions where the variables \( x_j, \ (j = 1, n) \) can only be integers.

**Definition:** The problem \( Z_1 = \max_{X \in R} F(X) \) will be referred to as an evaluation of problem (5), if \( K \subseteq R \) and \( f(X) \leq F(X) \) where \( \forall x \in K \).

Thus, from the definition of evaluation problem directly follows that \( Z_0 \leq Z_1 \) where \( \forall x \in K \).

The evaluation problem is formed on the basis of the Lagrange function. Specifically for the purposes of this study, the formation of the evaluation problem will be shown for a problem of integer linear optimization, and namely:

\[
Z_0 = \max_{X \in K} CX,
\]

where

\[
K = \{ X \mid AX = A_0, \ X \in M \}, \\
M = \{ X \mid 0 \leq X \leq D, \ X \text{ – integer vector} \}
\]

Here, when writing down the linear integer problem (6), the following notations were used:

\( A = \| a_{ij} \|_{m \times n} \) – constraint matrix;
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Optimizing The Maritime Shipping Management

\[ C = \begin{pmatrix} c_1 & c_2 & \ldots & c_n \end{pmatrix} - \text{row matrix of coefficients before the variables in the target function}; \]
\[ X = \begin{pmatrix} x_1 & x_2 & \ldots & x_n \end{pmatrix}^T - \text{column matrix of variables}; \]
\[ A_0 = \begin{pmatrix} b_1 & b_2 & \ldots & b_m \end{pmatrix}^T - \text{column matrix of free terms}; \]
\[ D = \begin{pmatrix} d_1 & d_2 & \ldots & d_n \end{pmatrix} - \text{row matrix of constants constraining the variables } x_j, \]
\[ (j = 1, n). \]

When the constraints in the problem are added to non-negative weights \( l_i, (i = 1, m) \), the result is:
\[ \sum_{j=1}^{n} A_j(L) x_j \leq A_0(L), \]
where \( L = \begin{pmatrix} l_1 & l_2 & \ldots & l_m \end{pmatrix} \), \( A_j(L) = \sum_{i=1}^{m} a_{ij} l_i \), \( A_0(L) = \sum_{i=1}^{m} b_i l_i \).

Let us denote as \( R(L) \) the area
\[ R(L) = \left\{ X \left| \sum_{j=1}^{n} A_j(L) x_j \leq A_0(L), X \in M \right. \right\}, \]
and include the initial conditions in the Lagrange function. The result is:
\[ Z_0 = \max_{X \in R \ L} \min_{U \geq 0} \left[ CX + U (A_0 - AX) \right]. \]

When we change the order of seeking the maximum and minimum value, we see that:
\[ Z_0 \leq \min \Phi_L(U), \]
where
\[ \Phi_L(U) = \max_{X \in R \ L} \left[ CX + U (A_0 - AX) \right] = \max_{X \in R \ L} (C - UA)X + UA_0. \]

We will refer to the vector \( U^* \) for which the function \( \Phi_L(U) \) has its maximum value in the area \( U \geq 0 \) as the vector of Lagrange multipliers (Krass and Chuprinov, 2013). For these multipliers the following inequality is true (Tomlin, 1970):
\[ Z_0 \leq \Phi_L(U^*). \]

Before we proceed with construction of the evaluation problem for model (1)–(4), we will look at additional problems complementing the study.
As an example, let us consider a ferry with a total volume of holds and decks $V m^3$ and tonnage $P t$, which can be used to transport $n$ types of load (containers, pallets, etc.). A unit load of the $j$ type has volume $v_j$, weight $p_j$ and value $c_j$ ($j = 1, n$). It is necessary to select and load those unit loads whose total value is the maximum, taking into account the characteristics of the ferry in terms of capacity and tonnage.

The effectiveness criterion for first problem so formulated is the total value of loads of all kinds with which the ferry must be loaded. Here the control factors are the capacity and tonnage of the ferry, the characteristics of the load (value, volume and weight of unit load). Alternative problems would be such based on other possible combinations of type and quantity of the loads. If the quantities of loads of the $j$ type to be shipped are denoted as $x_j$ ($j = 1, n$), then the alternatives will be represented as an aggregate of loads to be shipped $\{x_1, x_2, ..., x_n\}$, but only those meeting the restrictions in terms of capacity and tonnage of the ferry.

With such formulation of the problem, its mathematical model will look as follows:

Find the maximum of the function

$$F(x_1, x_2, ..., x_n) = \sum_{j=1}^{n} c_j x_j$$

subject to these constraints:

- capacity

$$\sum_{j=1}^{n} v_j x_j \leq V,$$

- tonnage

$$\sum_{j=1}^{n} p_j x_j \leq P,$$

- variables

$$x_j \geq 0 (j = 1, n)$$ integers

It is quite natural to combine the constraints in terms of capacity and tonnage into one, so that the model now has the following simplified structure:
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\[
\max : F = \sum_{j=1}^{n} c_j x_j \quad (7)
\]

subject to constrains

\[
\sum_{j=1}^{n} (v_j + p_j) x_j \leq V + P, \quad (8)
\]

\[
x_j \geq 0 \quad (j = 1, n) - \text{integers} \quad (9)
\]

In professional literature the model (7) – (9) is known as the knapsack (back-pack) problem (Pisaruk, 2010). In spite of the fact that special methods of solving have been developed, we will attempt another, slightly different approach to solving this problem.

First of all let’s stipulate that the control parameters \( P > 0, \ V > 0, \ c_j > 0, \ v_j > 0, \ p_j > 0 \ (j = 1, n) \) are integers. This requirement is fully justified by the existing practice. Let us consider

\[
\frac{c_k}{v_k + p_k} = \max \left\{ \frac{c_j}{v_j + p_j} \right\} \quad (j = 1, n). \quad (10)
\]

We shall assume that not all \( c_j \ (j = 1, n) \) equal zero, i.e. \( c_k > 0 \).

Theorem: If the parameter \( c_k \) determined through equation (10) is divisor of the numbers \( c_j \ (j = 1, n) \), then

\[
x_k = \left[ \frac{V + P}{v_k + p_k} \right], \quad x_j = 0 \quad (j = 1, n; \ j \neq k) \quad (11)
\]

is the solution of the problem (7) – (9).

In order to prove this assertion we will examine the equivalent of problem (7) – (9): find the maximum of the function \( \frac{F}{c_k} \), given that:

\[
-\frac{F}{c_k} + \sum_{j=1}^{n} \frac{c_j}{c_k} x_j \leq 0, \quad (12)
\]
On the grounds of (11) and inequality (13) it follows, that all coefficients before the variables are non-negative numbers, which is why

\[
\frac{F}{c_k} = \left[ \frac{V + P}{v_k + p_k} \right], \quad x_j = 0 \quad (j = 1, n; j \neq k)
\]

is obviously solution to problem (12) – (14), and therefore (11) is solution to problem (7) – (9). To summarize, if

\[
\frac{F}{c_k} = \left[ \frac{V + P}{v_k + p_k} \right], \quad x_j = x_j^* \quad (j = 1, n; j \neq k)
\]

is solution to problem (12) – (14), then

\[
x_k = \left[ \frac{V + P}{v_k + p_k} \right] - \sum_{j=1}^{n} \frac{c_j}{c_k} x_j^*, \quad x_j = x_j^* \quad (j = 1, n; j \neq k)
\]

will be solution to problem (7) – (9).

The second supplementary problem will be formulated as follows. Suppose that a vessel with tonnage (capacity) \( P \) units must be loaded with \( n \) different types of loads. The aggregate costs \( c_j \) and weight (volume) \( a_j \) of one unit of load of the \( j \) type of load are known. The units of each load are indivisible, i.e. these are containers or other similar transport structures. The load must be assembled on the vessel in such manner so as to minimize the costs for its transport.

If we denote with \( x_j \) the units of the \( j \) type of load, which must be loaded, transported and unloaded from one port to another, then the mathematical model of the problem will look as follows:

Find the minimum of the function

\[
Z = \sum_{j=1}^{n} c_j x_j
\]

subject to the constraints
To find the functional equations of the problem, we assume that we have loaded $x_n$ units of the $n$ type load, where $x_n$ is integer, $0 \leq x_n \leq \left\lfloor \frac{P}{a_n} \right\rfloor$.

According to Bellman’s Principle of Optimality (Lalov et al., 1973), the remaining tonnage (capacity) $P - a_n x_n$ should be used efficiently. We then introduce the function $f_n(P)$, i.e. the minimum value of transport of type $n$ loads which can be loaded on vessel with tonnage (capacity) $P$.

Thus, the aggregate costs of the transport for solution $x_n$ will be

$$c_n x_n + f_{n-1}(P - a_n x_n).$$

Since $x_n$ is an integer from the closed interval $[0; \left\lfloor \frac{P}{a_n} \right\rfloor]$, then the optimal solution with respect to $x_n$ is the one minimizing the expression (18), i.e.:

$$f_n(P) = \min_{0 \leq x_n \leq \left\lfloor \frac{P}{a_n} \right\rfloor} \{c_n x_n + f_{n-1}(P - a_n x_n)\},$$

for $n \neq 1$, and if $n = 1$,

$$f_1(P) = \min \{c_1 x_1\} = c_1 \left\lfloor \frac{P}{a_n} \right\rfloor.$$

Thus we arrive at a problem which can be solved using the dynamic optimization methods (Spiridonov, 1978).

After this preparation, let us focus on the formulation and solution of the evaluation problem for models (1) – (4). For the purpose of formulation, we will include the constraints (3) in the Lagrange function, while other constraints will remain in the same area where the minimization of the Lagrange function will take place. Thus, for model (1) – (4) in particular, we get:
\[
F = \min_{R} \max_{U} \left[ \sum_{i=1}^{m} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij}) x_{ij} + \sum_{j=1}^{n} u_j (b_j - \sum_{i=1}^{m} x_{ij}) \right] \geq \max_{U} \Phi(U) = \Phi(U^*),
\]

where

\[
R = \{ X \mid \sum_{j=1}^{n} \lambda_{ij} x_{ij} \leq a_i, (i = 1, m), 0 \leq x_{ij} \leq f_{ij} - \text{integers} \},
\]

\[
\Phi(U) = \min_{R} \left[ \sum_{i=1}^{m} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij}) x_{ij} + \sum_{j=1}^{n} u_j (b_j - \sum_{i=1}^{m} x_{ij}) \right] = \\
\sum_{i=1}^{m} \min_{R_i} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij}) x_{ij} + \sum_{j=1}^{n} b_j u_j
\]

\[
R_i = \{(x_{i1}, x_{i2}, \ldots, x_{in}) \mid \sum_{j=1}^{n} \lambda_{ij} x_{ij} \leq a_i, (i = 1, m), 0 \leq x_{ij} \leq f_{ij} - \text{integers} \}.
\]

To find the value of the function \( F(U) \) at a given point we need, according to (19), to solve \( m \) “knapsack problems”, i.e. problems such as (7) – (9), for whose linear solution an approach was proposed above.

It should be emphasized that the vector \( U^* \) can be found using the methods of linear programming (Atanasov et al., 2014), where the participating vectors can be constructed in the course of the solution. Indeed, we will note that the set \( R_i \) contains a finite number of points: \( R_i = \{ X_i^t \mid t \in T_i \} \).

We denote:

\[
\mu_i = \min_{R_i} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij} - u_j) x_{ij} = \min_{i \in T_i} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij} - u_j) x_{ij}^t.
\]

Then for \( \forall t \in T_i \) the following will be true

\[
\sum_{j=1}^{n} (c_{ij} + r_j d_{ij}) x_{ij}^t - \sum_{j=1}^{n} x_{ij}^t u_j \geq \mu_i
\]

and the problem of finding the maximum of \( \Phi(U) \) can be represented as follows:

\[
\Phi(U^*) = \max \left( \sum_{i=1}^{m} \mu_i + \sum_{j=1}^{n} b_j u_j \right)
\]

\[
\mu_i + \sum_{j=1}^{n} x_{ij}^t u_j \leq \sum_{j=1}^{n} (c_{ij} + r_j d_{ij}) x_{ij}^t, \ t \in T_i, (i = 1, m).
\]

Then we construct the dual problem:
\[
\min : \sum_{i=1}^{m} \sum_{t \in T_i} \left( (c_{ij} + r_jd_{ij})x_{ij}^t \right) y_{it}, \quad (21)
\]

\[
\sum_{i=1}^{m} \sum_{t \in T_i} x_{ij}^ty_{it} = b_j, (j = 1, n), \quad (22)
\]

\[
\sum_{t \in T_i} y_{it} = 1, (i = 1, m), \quad (23)
\]

\[
y_{it} \geq 0, (i = 1, m; t \in T). \quad (24)
\]

The number of vectors of problem \((21) - (24)\), which is the same as the number of points in the set \(R_i (i = 1, m)\) is obviously too large. But in order to solve problem \((21) - (24)\) it is not necessary to “run along” all vector. As with the decomposition method (Goldstein and Yudin, 1971), it is possible at each step of the simplex algorithm to look for that vector for which the condition of the problem is violated to the greatest degree. Specifically for the variables \(y_{it}\) this condition is determined through \((20)\). Consequently, for each index \(i\) we must find such vector \(X_i^t\), for which the expression

\[
\sum_{j=1}^{n} (c_{ij} + r_jd_{ij})x_{ij}^t - \sum_{j=1}^{n} x_{ij}^t u_j = \sum_{j=1}^{n} (c_{ij} + r_jd_{ij} - u_j)x_{ij}^t
\]

has its minimum value, where \(u_j\) are resolving multipliers corresponding to the constraints \((22)\). Therefore, in order to determine the vectors to be included in the basis of problem \((21) - (24)\), we need to solve \(m\) problems of the type:

\[
\sum_{j=1}^{n} (c_{ij} + r_jd_{ij})x_{ij}^t - \sum_{j=1}^{n} x_{ij}^t u_j = \sum_{j=1}^{n} (c_{ij} + r_jd_{ij} - u_j)x_{ij}^t \quad (25)
\]

\[
\sum_{j=1}^{n} \lambda_{ij}x_{ij} \leq a_i, \quad (26)
\]

\[
0 \leq x_{ij} \leq f_{ij}; \quad x_{ij} \text{ integers for } j = \overline{1, n}. \quad (27)
\]

Each of these problems \((25) - (27)\) belongs to the class of the operational problems \((7) - (9)\) discussed above (note though that the index \(i\) is invariable), for whose solution the dynamic programming method was recommended. If \(F_i(U) - \mu_t < 0\), where \(\mu_t\) is a resolving multiplier corresponding to \((23)\), then the optimality condition \((20)\)
will be violated and the vector \( X'_i = (x'_i, x'_i, \ldots, x'_i, 0, \ldots, 1, 0, \ldots, 0) \) whose components are the solutions of problem (25) – (27) should be introduced to the basis of problem (21) – (24). After a finite number of steps we will arrive at the optimal solution of this problem. The resolving multiplier \( U^*_j \) corresponding to (22) determines the vector whose components are the Lagrange multipliers, and \( F_i = \Phi(U^*) \) determines the evaluation sought.

Overall, it should be noted that model (1) – (4) may in the most general case be defined as a transportation problem. In these problems, as is well known (Zhel-yazkova, 2011), the variables \( x_{ij} \) participate in exactly two of the constraints: they appear once in each. This allows the evaluation problem to be constructed in another manner, for example by including another subsystem in the Lagrange function. In particular, in the case of the examined model (1) – (4) we may include in the Lagrange function the following constraint:

\[
\sum_{j=1}^{n} \lambda_{ij} x_{ij} \leq a_i
\]

and take into account that \( 0 \leq x_{ij} \leq f_{ij} \); \( x_{ij} \) are integers. Thus we have

\[
Z(X) \leq \max_{U \geq 0} \left\{ \sum_{j=1}^{n} \min_{R_j} \left( \sum_{i=1}^{m} (c_{ij} + r_{ij}d_{ij} + \lambda_{ij} u_j) x_{ij} - \sum_{i=1}^{m} a_i u_i \right) \right\},
\]

where

\[
R_j = \left\{ x_{ij} \left| \sum_{i=1}^{m} x_{ij} = b_j, 0 \leq x_{ij} \leq f_{ij}, x_{ij} \text{ integers (j is invariable)} \right. \right\}.
\]

The optimal solution of the sub-problem to the evaluation problem (28) can easily be found by applying known methods (Kenderov et al., 1989). It should be emphasized that the evaluation determined through (28) coincides with the solution of model (1) – (4).

Indeed, when the set

\[
R'_j = \left\{ x_{ij} \left| \sum_{i=1}^{m} x_{ij} = b_j, 0 \leq x_{ij} \leq f_{ij}, (j \text{ is invariable}) \right. \right\}
\]

is formed and the duality theorem (Atanasov, 2009) is applied, we have
\[ F = \min_{X \in \mathbb{R}} \max_{U \geq 0} \left[ \sum_{i=1}^{m} \sum_{j=1}^{n} (c_{ij} + r_j d_{ij})x_{ij} - \sum_{i=1}^{m} u_i \left( a_i - \sum_{j=1}^{n} \lambda_{ij} x_{ij} \right) \right] = \]

\[ = \max_{U \geq 0} \left\{ \sum_{j=1}^{m} \min_{R_j} \left[ \sum_{i=1}^{m} \left( c_{ij} + r_j d_{ij} + \lambda_{ij} \right) x_{ij} - \sum_{i=1}^{m} a_i u_i \right] \right\}. \tag{29} \]

We will further note, that (29) is different from (28) only insofar as when defining the area \( R_j \) the variables \( x_{ij} \) must be integers, while in (29) there is no such requirement.

Regardless, it should be taken into account that the optimal solution of sub-problem (29) also will consist of integers, which ensures the coincidence of (28) with (29).

When looking for Lagrange multipliers for different integer transportation problems, the general scheme for solving the problem of linear programming remains unchanged. Changes occur only to the sub-problems used to determine the basis vectors, as well as to the type of these vectors. In particular, as regards model (1) – (4), the sub-problem performing the function of (25) – (27) will be expressed as follows:

\[ \min \left\{ \sum_{j=1}^{n} (c_{ij} + r_j d_{ij} - u_j) x_{ij} + s_{ij} y_{ij} \right\} \left[ \sum_{j=1}^{n} x_{ij} = a_i ; 0 \leq x_{ij} \leq f_{ij} y_{ij} ; y_{ij} = y_{ij}^2 , j = 1, n \right]. \tag{30} \]

When \( a_i \) and \( f_{ij} \) are known, an optimal solution for (30) may be sought for integer values of \( x_{ij} \). This allows us to reduce (30) to the generalized knapsack problem (15) – (17) expressed as follows:

\[ \min \left\{ \sum_{j=1}^{n} f_{ij} \right\} \left[ \sum_{j=1}^{n} k_{jp}^{(i)} z_{jp}^{(i)} \leq a_i , \sum_{j=1}^{n} z_{jp}^{(i)} \leq 1 ; z_{jp}^{(i)} \in \{0, 1\} \right], \tag{31} \]

where \( z_{jp}^{(i)} = 1 \), if \( x_{ij} = p \), \( y_{ij} = 1 \) and \( z_{jp}^{(i)} = 0 \) in all other cases. Then

\[ k_{jp}^{(i)} = (c_{ij} + r_j d_{ij} - u_j) p + s_{ij}. \]

Problems (30) and (31) can be solved through the dynamic programming method. It is based on the basic functional equations and recurrent correlations (Spiridonov, 1978). Specifically for the case at hand, given that the index \( i \) is invariable, applied to (25) – (27), it can be described in the following way. Let

\[ \phi_k l = \min \left\{ \sum_{j=1}^{n} (c_j - u_j) x_j \left[ \sum_{j=1}^{n} \lambda_j x_j \leq l \right] , 0 \leq x_j \leq f_j - \text{integers}, (j = 1, n) \right\}. \]
Then
\[ \varphi_{k+1}(l) = \min_{x_{k+1}=0, l_{k+1}} \{ (c_{k+1} - u_{k+1})x_{k+1} + \varphi_k (l - l_{k+1}x_{k+1}) \}, \]  
(32)
where \( \varphi_k (l) = \infty \), if \( l < 0 \).

The function \( \varphi_k (l) \) is calculated directly, while \( \varphi_{k+1}(l) \) is derived from (32) where \( k = 1, n - 1 \). The value \( \varphi_n (a) \) determines the minimum value sought, and this process, which is the reverse process to the calculation of the values of \( \varphi_k (l) \), allows finding the optimal solution of the problem. The calculation of the values of \( \varphi_k (l) \), along with the finding of conditionally optimal values can be performed easily by using special tables (Atanasov, 2015).

In conclusion, we should point out that after some adaptation the proposed approach can be successfully applied to solving other types of transportation and logistics problems related to discrete variables. Similarly, the calculation procedure at the different stages of solution of the model (1) – (4) is not associated with major difficulties, since the individual blocks of sub-problems are in fact optimization problems, for which special methods were proposed, and besides these can be dealt with using software.

References

PRICE ASPECTS OF “CRAFT” BEER’S COMPETITIVENESS IN BULGARIA

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Abstract

“Craft” beer is a special part of the “Wine production” class which attracts even more consumers in the last couple of years. The opportunity for an informed choice of a product or service that satisfies specific needs of consumers shifts the focus from the low price to the product of high value for which it must be paid. The goal of this article is to empirically develop the determinants that influence the choice of “Craft” beer based on theoretically proven determinants of competitiveness of price. The scientific tasks can be summarized as: developing the determinants that form the value accepted and theoretical motivation of its relation with price flexibility; theoretical motivation of the relation between price flexibility and price competitiveness; empirical development of the key determinants of price competitiveness of the “Craft” beer in Bulgaria. In this paper there are used the methods of analysis and synthesis, surveys through questionnaires, statistical methods, market research and others.

Introduction

At the onset of the second decade of XXI C there started a wave of developing new “micro” and “small” enterprises in class C.11.05 “Beer production”. Despite the competitive pressure from leaders in the branch they adapt successfully and establish themselves on the market by managing to attract more real clients. While looking for advantages, they are forced to offer their clients a unique product through which to justify its higher price. It is for this reason that the interest in the so-called “craft beer” has grown recently. According to the Association of home breweries in Bulgaria, set up in 2013, “Craft beer” is produced in small, usually family breweries which produce original, special beers with high quality, traditions and they are interesting for consumers (Association of home breweries in Bulgaria, 2013). Defined in this way and based on its unique characteristics, the Craft beer has a set of tools through which one can justify the competitiveness of the price of the product offered. According to

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The Union of breweries in Bulgaria, the registered Craft breweries in the country in 2010 were 4 and in 2014 there were already 8 of them which, having in mind the amount of investment, is really a substantial growth.

The subject of this survey is to identify the factors that influence the price competitiveness of the Craft beer and the object are the consumers of this product in Bulgaria.

The objective of this article is on the ground of theoretically proven determinants for competitiveness of the price to develop empirically those that influence the consumer’s choice of Craft beer.

To achieve these goals the following scientific tasks were solved:
1. Developing the determinants which set up the value perceived and theoretical justification of its relation to price flexibility;
2. Theoretical justification of the relation between price flexibility and price competitiveness;
3. Empirical development of the key determinants of the price competitiveness of “Craft” beer in Bulgaria.

In the survey there are used the methods of analysis and synthesis, questionnaire surveys, statistical methods, market research and others. For the analysis the software product SPSS is used.

1. Theoretical grounds for competitiveness of price

The development of the global corporate structures and the emergence of a myriad of products, brands and producers of products that compare in respect to quantity, quality and image, presuppose the search for new forms of competition and manifestation of the competitive behavior of companies. According to Prahalad and Ramaswamy (2009), “The new competition” is based on the assumption that “the consumer and the company are intimately involved in the mutual creation of values that are unique for the individual consumers and sustainable for the company”. Prahalad and Ramaswamy (2009) add that “the paradox in the new economy is that consumers have a bigger choice which brings them less satisfaction, while producers have more strategic options that bring less revenue”.

Acquiring ownership of direct competitors on behalf of big world companies allowed them to increase hugely their presence on the market. As a consequence a number of companies lose their identity, while the identikit air of the products and services offered repulses their clients. That is why clients are not always loyal to the “lack of identity” of the company products to which they have recently been attached.
The development of the paradigm for creating values in the relationship between retailer and buyer breaks the classical notion of competitiveness. The development and the even greater accessibility of information give consumers a new vista and opportunity for informed choice. This gives the ground to think that consumers “evolve” not only in respect to their choice but also in respect to how they understand price behind which they see a number of factors which predetermine their preferences.

Michael Porter (2005, p. 75), who has contributed most significantly to modern science in the field of competition and competitiveness, defines it as “the characteristic feature of goods, services and subjects of market relations to set foot on the market next to the existing there similar goods, services or competing subjects of market relations”. In the context of this survey and to achieve its goals with “competitiveness” one should mean: the ability to retain and increase clients’ share; the ability to create added value which satisfies its creator and user in respect to contents and quantity; the ability to manage a company’s competitive advantages effectively.

Therefore, the improvement of companies’ market presentation should comply with revealing the key determinants which make products and services preferable. As a common equivalent and measurer of a product’s value for the client, price plays a vital role in the competition race. Products’ ability to compete is determined by some basic characteristics which define the so-called competitive advantages in respect to: innovation of the product, its quality, economic use of resources, after-sales service, consumer’s value of the product, the way the product is offered and its accessibility, the cost for creating it which concerns the price anyone is ready to pay for the set of these and other parameters of products and services.

According to M. Porter (2005, p. 27) the competitive advantage stems from the value which the company creates for its consumers and which exceeds the expenses for creating it. Shoeu (2008, p. 12) states his thesis that “competitive advantages are key factors which need to be maintained and developed and the issue is which competitive advantages are sustainable in time and can bring the company more profits”. This gives us enough ground to think that the characteristics of products or services offered by economic subjects are of particular importance for competitiveness in modern conditions. These features can be of different nature and can concern the product itself; the necessary or added services which accompany the basic product/service or the specifics of production, distribution or personal sales; as well as the company.

Creating and maintaining sustainable competitive advantages concern also the price a consumer is ready to pay for the value he is going to receive when buying a
particular item. Having this in mind, more than 25 years ago Savinov wrote (1985, p. 12): “The higher the consumer value, revealed through the quality of a product, the more needs it satisfies and the smaller its value presented through its expenses, the more competitive the product is”. In a similar statement with “expenses” one should understand all resources (financial and non-financial) that a consumer should give up in order to get a particular product. When this comparison between benefits and expenses for the consumer refers to a financial resource, it is called an economic effect for the consumer. In case it refers to a non-financial resource, it is called a psychological effect. That is why one can state that the purchasing decision is a set of assessing a number of interrelated factors which need to be identified, ranked and evaluated by consumers. This decision is not made in isolation but within the framework of a competitive market where prices still play a vital role as a measurer of the consumer’s readiness to do without something in order to get a particular product or service. That is why the bigger fight for competitive dominance on the market turns the processes of company pricing into an activity that is governed by a company’s strategic marketing objectives. This conclusion is based on the fact that more often when setting price levels one has in mind not only the impact of company internal factors and external opportunities and threats, but also the value in all its forms which is created in the process of economic interaction between market participants.

In economic literature there exists the thesis that the use of price in competitive fight is directly linked to product differentiation (Alexandrov, 1999). This, in turn, underpins the supply and demand for unique product characteristics and is aimed at attracting clients’ attention (this thesis is the basis of defining “Home brewing”). An item is considered competitive if its selling price, design and quality do not fall behind the characteristics of the similar goods available on the marker (Tihonov, 1985, p. 24). Moreover, a business should strive to supply a strictly individualized product with unique characteristics, whose selling price should take into consideration the client’s assessment of its value. Chen and Pearcy (2010, p. 674) speak of the effects of applying the theory of “dynamic pricing” for increasing competitiveness and attracting clients. What is specific about it is exactly the method to differentiate consumers, to pay special attention to the quality of the products and services offered to the existing clients, while the clients of the rivals’ products and services are attacked with differentiated price offers depending on the frequency of purchasing, quality in demand and others. It is similar methods that are defined as “competitive actions” and they show clearly and indisputably that price competitiveness is possible and it is done not only through reducing the price, but also through other activities which allow selling a product at a high price and this product is preferred by a specific circle.
of consumers (20% of the clients can account for 80% of a company’s revenues). That is why it is important to search for an opportunity to offer products of high value for consumers who can appreciate it and are ready to pay for it.

In support of a similar viewpoint is Clark and Fujimoto’s thesis (1991, p. 1), who in a publication in the 1990s say that “the new dimensions in the competitive fight between industrial companies, focused on product development, are driven by three basic powers: the intensity of international competition, market fragmentation and clients’ whims, and the variety and development of technologies”. It is the focus on clients’ whims that is the key to the competitiveness of “Craft” beer worldwide.

The changing relations among various market participants always lead to transformation and a different viewpoint on the elements of the marketing mix. The concept of transforming the “4 Ps” into “4 Cs”: “Product – Consumer wants and needs; Place (Distribution) – Convenience; Price – Evaluation (Cost for the client); Promotion – Communication (Symbolization)” (Kotler, 2005, p. 65; Stoychev, 2008, p. 33; Danchenko and Ivanova, 2006, p.21) signals clearly the dynamic changes taking place not only in practice, but in theory as well. It is these changes that allow us to identify the new place of price in the competitive race of goods which is revealed in consumer’s individual assessment of what he receives. Hence we think that price competitiveness, rendered through the prism of modern dynamic processes, needs to be viewed rather as a competition of prices through products’ characteristics and values rather than competition between products through their prices (Ivanov, 2016, p. 59).

The primary idea for such definition lies in the necessity for clients to receive a significant difference between the cost (worth, lower limit of price) of a product or service and the benefits that a client will receive from the product (value, upper limit of price). The range between the two defined limits of price, called “economic effects of production and consumption…” (Blagoev, 2013, p. 99) that is distributed between the producer and consumer, happens to be a very good starting point for defining key determinants for assessing and increasing price competitiveness. To a certain degree this resembles Prahalad and Ramiswamy’s idea (mentioned earlier in this article) about “created shared value” which is to be distributed fairly between producer/ distributor and clients.
Distributing this effect among producers and clients reasonably and with balance turns into a key source of competitive advantage (Pain, 2005, p.102). Porter and Kramer (2011, p. 64-70) support and develop the idea about distributing value (the cost as they call it in their publication) and add that such distribution cannot be defined either as social responsibility or philanthropy, it is rather a tool for achieving advantages and success for business through change in the way of public thinking. Rendering the idea of economic effect through the mediatory prism of the value approach of pricing and building partner relations with clients shows that price flexibility depends on the mutually created and accepted value of products and services. Moreover, the basic task of modern pricing therefore needs to be the efficient management of “the economic effect” for providing a considerable degree and market freedom in setting a competitive price which is a prerequisite for increasing price competitiveness without this being tied to a decrease in its level.

Fig. 1 illustrates the idea of distributing the economic effect, as well as the place of the value of this effect. The conclusions drawn from it are that the bigger the range between the cost and the accepted value of the product or service, the greater flexibil-
ity in setting the price for the company. Thus, even higher price levels for products bringing their consumers a value whose cost according to them exceeds the market price, will be competitive.

Accepting the value approach as a leading paradigm in developing the factors that determine the price aspects of competitiveness and citing a construed conceptual model for assessing the price competitiveness of products and services (Ivanov, 2016, p. 154), we can set forth three determinants whose effect influences the way a consumer accepts the price, respectively its competitiveness:

- consumer preferences which fix the upper limit of the value (accepted value);
- the product and inner company conditions which tie the cost with the accepted value;
- the market conditions which set up competitive relations.

2. Methodology for studying the factors of competitiveness of the “Craft” beer in Bulgaria

In this survey the objects are only the end clients of the “Craft” beer which means that the remaining market participants will be eliminated in the sample of the survey. Thus, as an end client of the “Craft” beer one should mean a person consuming beer, aware of the products of “Craft” breweries; he prefers them and is able to give information about the reasons motivating him to choose this product.

The subject of the survey is to identify the factors which influence the competitiveness of the prices of the “Craft” beer.

The objective of the survey is to develop empirically the determinants which influence consumers’ choice of the “Craft” beer in Bulgaria.

To do the survey it is planned to apply a descriptive research programme due to the requirements of the assigned objective. Its main task is aimed at studying the profile of consumers of “Craft” beer in Bulgaria, their specific perceptions and assessment of particular characteristics of the product, market, brand and relations with the producer that influence the consumer choice. To gather the necessary empirical data a structured on-line questionnaire is designed.

To do the main survey a sample approach is chosen. For convenience the size of the sample is 366 people and the general aggregate includes the consumers of “Craft” beer who meet the assigned criteria in the object of this survey. One can state that in its structure the sample resembles the general aggregate in the criteria gender of respondents (see graph 1).
For the objective of this survey the sample unit is the particular individual who drinks beer and the units from which data is gathered are people above 18 due to the nature of the product (an alcoholic drink prohibited for people under 18). According to data of NIS (National institute of statistics) for 2015 in Bulgaria in the age range above 18 there live 2975135 men and 3201151 women which corresponds with the distribution mentioned above.

Graph 1. Distribution of respondents according to gender

Gathering data is done through spreading the questionnaire through various types of web sites. For the objectives of the main survey the analysis of the empirical data is made with factor analysis, making all preliminary checks for meeting the requirements for doing it.

On the ground of preliminary studies and thorough interviews with real clients of the “Craft” beer in Bulgaria, there were developed exit variables in three basic factors as defined in the theoretical analysis: preferences of clients, products and inner company conditions, market characteristics.

A questionnaire is designed with three sets of questions. The first one “General questions” aims at discovering how much beer Bulgarians drink and whether they are familiar with the products of small “Craft” breweries. The aim of the second set of questions is to determine the influence of the particular exit variables on the clients’ choice in making purchasing decision for the “Craft” beer; the third set of questions concerns demography.
The survey was carried out between 6 January 2016 and 12 January 2016. We should point out that the survey needs to be defined as a “non-representative sample survey” since the sample is formed according to convenience. We think that because of the way of doing the survey variations in the results are possible, that is why the applied set of tools corresponds with the sample and the ranges that characterize the questions in the survey.

3. Factors of competitiveness of the “Craft” beer in Bulgaria

The results of the survey give us the ground to create a profile of the clients who drink the “Craft” beer in Bulgaria. The descriptive analysis of the first set of questions shows that only 11% of 366 people total answer that they do not drink beer (see graph 2).

Graph 2. Do You Drink Beer?

This shows that traditionally a Bulgarian drinks beer and it is not by chance that we rank 14th in Europe (data of the Association of beer producers in Bulgaria) and share the place with Belgium – one of the leading producers of beer. Interesting results concern the frequency of drinking beer – 19%, almost one fifth of the respondents (324 people said they drink beer) drink beer every day. 37% of the respondents drink 2-3 times a week, 29% drink 2-3 times a month. About 15% of the people drink beer several times a year. Of interest was the question about the quantity that each of the respondents has (the unit is a bottle of 0.5 l). Most of respondents – 56% drink
one beer. The share of people who drink 1-3 beers is not small, only 6% of the respondents define themselves as “heavy” drinkers – more than 3 beers.

Asking the question “Are you familiar with the products of the “Craft” breweries in Bulgaria?” aims at differentiating from the total number of 324 beer-drinking respondents those who are familiar with the product whose factors of competitiveness we look for. 174 respondents answered positively. Because of the fact that the second set of questions is too specific and concerns consumer assessment of a product category which they need not only to be familiar with but also use, after question №5 “Have you drunk “Craft” beer of a Bulgarian producer?” we reduced the respondents to 153. Based on their answers we can make a profile of the client who drinks Bulgarian “Craft” beer: mainly men, aged about 44, they earn average and high income and live in large towns and cities. A similar characteristic is due to: first, the “Craft” beer has much higher alcohol degree which attracts men more; second, the price at which these products are sold is to a considerable degree affordable for people with average and high income and third, the access to these products in the large towns and cities is much easier.

Based on the profile and the reduction of respondents an analysis of the replies of 153 people was made concerning the reasons for their choice of the “Craft” beer.

The applicability of the factor analysis has been determined with the help of the Bartlett’s Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy. The Bartlett’s test is meant for testing the zero hypothesis which claims that the variables do not correlate with each other, therefore the correlation matrix is an identical matrix, in it the values of the correlation coefficients along the diagonal are 1 and all remaining ones – 0. Table 1 clarifies that the value of the Bartlett’s test is 1187.787, i.e. this value is high enough to reject the zero hypothesis about a lack of correlation between variables. The Kaiser-Meyer-Olkin (KMO) Measure, in turn, compares the magnitudes of the monitored correlation coefficients with the magnitudes of the partial correlation coefficients. The small values of the measure (below 0.5) show that the correlation coefficients between the pairs of variables cannot be explained by other variables, i.e. one cannot claim the presence of some more significant hidden factors, which makes the factor analysis inapplicable. Table 1 shows that the value of the measure is above 0.642 which proves that the factor analysis can be accepted as a valid research method in this survey.
The data in Table 2 and Table 3 show that the designed assessment ranges in regard to developing the factors of competitiveness of the “Craft” beer can be accepted as valid. The discriminative justification of the ranges is proven by the factor analysis. The results from the varimax rotation of the 16 components show that instead of three, as stated in the theoretical model, they form four basic factors: consumer attitudes and preferences, product characteristics, inner company conditions which are set as a new separate determinant of competitiveness and market conditions.

The tested ranges have also good convergent validity. As a result of the varimax rotation there are determined three factors with eigenvalues above 1 (Table 2). They explain 59,286% of the variation of the 16 exit variables. The first factor “consumer attitudes and preferences” explains 25,781% of the variation. It comprises the variables: promotions, advertisement, customer care, recommendations by clients and product offers of competitors. The second factor “product characteristics” explains 11,467% of the variation. It includes the variables: variety of tastes, variety of colours, durability, density of beer, degree of filtering and alcohol content.

### Table 1

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin Measure and Bartlett’s Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser-Meyer-Olkin Measure of Sampling Adequacy.</td>
</tr>
<tr>
<td>Bartlett's Test of Sphericity</td>
</tr>
<tr>
<td>df</td>
</tr>
<tr>
<td>Sig.</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Components</th>
<th>Eigenvalues</th>
<th>Sum of quads</th>
<th>Rotated sum of quads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of variation</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>1</td>
<td>4,588</td>
<td>28,676</td>
<td>28,676</td>
</tr>
<tr>
<td>2</td>
<td>2,500</td>
<td>15,623</td>
<td>44,299</td>
</tr>
<tr>
<td>3</td>
<td>1,676</td>
<td>10,477</td>
<td>54,775</td>
</tr>
<tr>
<td>4</td>
<td>1,242</td>
<td>7,763</td>
<td>62,539</td>
</tr>
</tbody>
</table>
The third separate factor is “inner company conditions” which explains 11.316% of variations. It includes: production technologies and quality of the used resources. The fourth factor “market conditions” explains 10.723% of the variation and comprises the variables: image of the producer in public, product offers of competitors, prominence of the producer company and access to the product. All variables meet the requirement for factor load of 0.5. This gives us the ground to accept the set factors and the variables they include as valid.

The identified factors and the variables comprising them do not coincide with the theoretically developed three factors in the conceptual model (Ivanov, 2016), because they were suggested as a result of a survey of the conceptual model, i.e. in it the survey was done by principle instead of a particular product. That is why the factor “product characteristics and inner company conditions categorized then, is divided into two separate factors in this survey. We could say that the result satisfy its objectives. Therefore we can draw the conclusion that the presented data give the ground to accept that the applied set of tools is reliable enough and valid for the objectives of the survey.
### Table 3

**Rotated factor matrix (n=153)**

<table>
<thead>
<tr>
<th></th>
<th>Factor</th>
<th>Consumer attitudes and preferences</th>
<th>Product characteristics</th>
<th>Inner company conditions</th>
<th>Market conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productions technologies</strong></td>
<td>-0.046</td>
<td>-0.110</td>
<td><strong>0.841</strong></td>
<td>0.239</td>
<td></td>
</tr>
<tr>
<td><strong>Quality of the used resources</strong></td>
<td>0.026</td>
<td>0.337</td>
<td><strong>0.781</strong></td>
<td>-0.260</td>
<td></td>
</tr>
<tr>
<td><strong>Variety of beer flavours</strong></td>
<td>-0.120</td>
<td><strong>0.647</strong></td>
<td>0.100</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td><strong>Image of the producer in the public</strong></td>
<td>0.384</td>
<td>0.078</td>
<td>0.086</td>
<td><strong>0.722</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Variety of beer colours</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Promotions</strong></td>
<td>0.006</td>
<td><strong>0.797</strong></td>
<td>-0.003</td>
<td>0.190</td>
<td></td>
</tr>
<tr>
<td><strong>Advertisement</strong></td>
<td><strong>0.832</strong></td>
<td>-0.118</td>
<td>0.054</td>
<td>-0.099</td>
<td></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td><strong>0.635</strong></td>
<td>-0.289</td>
<td>-0.141</td>
<td>0.318</td>
<td></td>
</tr>
<tr>
<td><strong>Density of beer</strong></td>
<td>-0.123</td>
<td><strong>0.695</strong></td>
<td>0.133</td>
<td>0.131</td>
<td></td>
</tr>
<tr>
<td><strong>Customer care</strong></td>
<td>-0.106</td>
<td><strong>0.770</strong></td>
<td>-0.046</td>
<td>0.240</td>
<td></td>
</tr>
<tr>
<td><strong>Recommendations from clients</strong></td>
<td>0.709</td>
<td>0.390</td>
<td>0.090</td>
<td>0.294</td>
<td></td>
</tr>
<tr>
<td><strong>Degree of filtration</strong></td>
<td><strong>0.617</strong></td>
<td>0.410</td>
<td>0.171</td>
<td>0.163</td>
<td></td>
</tr>
<tr>
<td><strong>Product offers of leading companies</strong></td>
<td>0.304</td>
<td><strong>0.713</strong></td>
<td>0.390</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td><strong>Prominence of producer company</strong></td>
<td>0.171</td>
<td>-0.188</td>
<td>0.219</td>
<td><strong>0.697</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Access to product</strong></td>
<td>0.223</td>
<td>-0.369</td>
<td>-0.190</td>
<td><strong>0.673</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Alcohol content</strong></td>
<td>-0.142</td>
<td>0.015</td>
<td>-0.331</td>
<td><strong>0.668</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.097</td>
<td><strong>0.851</strong></td>
<td>-0.227</td>
<td>0.190</td>
<td></td>
</tr>
</tbody>
</table>

*Method of extraction: Principal Component Analysis.*

*Method of rotation: Varimax with Kaiser Normalization.*

*a. Rotation converged in 8 iterations.*

The final question in the questionnaire survey in the second set was directed at the value respondents received from the products of the “Craft” breweries and the price the products were offered at: Would you pay a higher price for a “Craft” beer? The answer to this question is a firm “YES” from 82% of the participating 153 respondents. These results are indicative, especially having in mind that the price of a glass bottle of 0.500 l in the store is up to 2-3 times higher than that of mass beers.
4. Conclusion

The results from the survey confirmed our position that it is possible for the high prices to be competitive when a product of unique characteristics for a particular consumer segment is offered. This is due to the fact that the “evolution” of consumers and the use of “client-centred” models of business management attract and retain clients on the ground of the value created by the two interested parties – producers and clients. This value, expressed through the factors of competitiveness, allows companies to sell their products to clients who are ready to pay for having unique experience from the purchase. Carrying out similar surveys provide an answer to the question why the high price for a product that provides the value wanted by the consumer is competitive.

Today, when the public has easier access to information and products with various characteristics and quality, the informed choice and getting special attitude from the company whose product is used is the key to competitiveness. That is why the indiﬀerence of products produced by companies which are interested predominantly in the price of their shares and conquering new territories, makes possible the survival and development of the “Craft” breweries in Bulgaria.

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MEASURING THE IMPACT OF THE QUALITY MANAGEMENT SYSTEMS ON THE COSTS OF NON-COMPLIANCE

Donica STOYANOVA

Abstract

Determining the impact of the implemented quality management system on the costs of non-compliance is significant for every organization which has adopted the Bulgarian Institute for Standardization БДС EN ISO 9001:2008 in order to enhance its efficiency. The main objective of the present paper is to provide an algorithm by means of which the organization can make estimates concerning the contribution of the present system for cutting these costs. A set of indicators is proposed for monitoring the means spent for non-conformance needs incurred in the years before and after the QMS implementation, as well as a scheme for determining the real savings the company has achieved by reducing the considered costs using the system tools.

Keywords:
quality management system, costs, non-compliances, measuring.

Introduction

Nowadays more companies rely on implementing the quality management system (QMS) to increase their competitiveness. Undoubtedly, the existence of a certified system improves company’s image to its current and potential partners (Costa & Martinez, 2004), aids eliminating barriers when entering new markets (Casadesus et al., 2001) and guarantees an access to procurement contracts. However, this does not restrict the positive influence of its operation. The successfully implemented QMS is able to entail a significant cost cutting in the company, especially concerning the so called “non-conformance costs” – additionally spent means for wiping out the results of production imperfections. (Nanda, 2005).

Irrespective of whether they arise during the production process, caused by deviations from the product’s characteristics, or at a later stage, as a result of a client’s lack of satisfaction, the non-conformance costs are able to divert significant company’s funds which are required to finance its main operations. Due to its initiatives and tools QMS has the potential not only to cut costs but also to find the reasons for their origin and anticipate suitable corrective actions which do not admit their repeated occurrence.

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The purpose of the present article is to suggest an algorithm which would be able to determine the impact of the operating management system on the non-conformance costs in the industrial companies. Its main function is to offer a clear idea to the management team about the contribution of the implemented QMS for their reduction, and the need to determine effectiveness and efficiency of its operation. For the purpose of its design it is necessary to solve the following problems:

- To explain clearly the essence and structure of the non-conformance costs, as well as the mechanism by which the implemented QMS influences their reduction;
- To select indicators for measuring the impact of the implemented QMS on the nonconformance costs;
- To produce a scheme for determining the QMS impact on the analysed costs and specifying the funds savings made as a result of the system operation.

The objects of the present theoretical study are the industrial companies which possess an implemented and certified system for quality management.

1. Characteristics of the non-conformance costs

The non-conformance costs have been an object of research since the dawn of modern theories of quality management. They exist as elements in the researched PAF model by Juran (1951) and Feigenbaum (1956) for defining the quality costs; in the works of Crosby (1979) as a point of reference for arguments; serve as a basis for the developed in 1992 British standard BS 6143:1992 “A manual in quality management” By their nature they are company losses caused by the poor quality of its manufactured or delivered production. They might arise in cases when the product characteristics do not comply with manufacturing specifications or the particular client’s needs. All funds, spent on any identified non-compliance by separate economic elements are included in their composition.

Depending on the time and place of finding the particular non-conformance, they may be divided into two large groups: costs for internal non-conformance and costs for external non-conformance. The costs for internal non-conformance occur referring to noted mistakes and diversions found before delivering the product to the client. (Dyukendzhiev and Yordanov, 2012, p. 242). All funds spent and related to the next items fall into this category:

- All defective production which is not subject to correction /waste/;
- Processing and repair of correctable flaws in the manufactured products or their elements;
Carrying out additional monitoring initiatives and testing related to completed production.

Likewise, the external non-conformance costs are related to defects which are detected after the product has been delivered to the client. The funds spent on next items fall into this category:

- Expressed claims;
- Accrued fines, penalties and price discounts in cases of failure to comply with the contractual terms;
- Payment of liability claims pursued in a legal way concerning damages caused to the client from the product use.
- Warrantee repairs, checking and replacing the faulty products.

The reduction of non-conformance costs is an essential purpose for each company. They increase the total costs of the company, the cost of the manufactured produce and reduce company’s financial results. On the other hand, every external non-conformity causes not only material injury but also ruins the image of the company as a provider of high quality products and services.

The core objective of the quality management systems, developed in compliance with the clauses of BDS EN ISO 9001:2008, is to stipulate and conform to internal company regulations which will set up preconditions for reducing to a minimum the internal and external non-conformities. This can be achieved by:

1) Clearly defined authority and responsibilities of the recruited staff concerning the processes carried into effect in the company;
2) A set of advance planned preventive and monitoring events for ensuring the quality of the delivered products;
3) Methods for carrying out data analyses of previously originated non-compliances and looking for reasons of their occurrence;
4) Tools for implementing corrective and preventive activities and continuous improvement.

The described elements, which were effectively developed and implemented, are able to reduce significantly the non-conformance costs in the organization.

2. Indicators for measuring the impact of the implemented quality management system on the costs of non-conformance

The extent to which the operating QMS has managed to cause a reduction of non-conformance costs is an issue which worries every organization which adopted
the principles of The Bulgarian Institute for Standardization БДС EN ISO 9001:2008 with the aim to enhance its efficiency. In order to determine the contribution of the system in the considered direction, the appropriate indicators need to be selected and their significance has to be traced before and after their implementation.

In scientific literature there is no agreement over the issue what indicators are appropriate to be used when comparing the costs of non-conformance which occurred at different time periods. Some authors (Institute of Management Accountants, 1993) put reliance on the direct, absolute comparison of the examined costs in different years of the investigated time frame. For these periods they calculate all funds spent because of the emerged internal and external non-conformance costs and directly compare their values. Although this approach is easy to apply, it is extremely inaccurate, in our view. We, therefore, consider that it possesses two major weaknesses which make it unreliable.

1) The volume of production and sales respectively which caused the particular costs of non-conformance are not taken into account. As far as they are in a direct correlation if the manufactured or sold volumes are significantly reduced the funds spent on non-compliances are expected to follow the same direction of change. If the absolute indicators are applied for the needs of the analysis they will render an account that there is a reduction of investigated costs which might lead to misleading conclusions about the efficiency of the applied measures for that purpose.

2) Similar indicators are the bearers of the inflation which is valid in the country. That, especially in long-term aspect may distort the obtained results and lead to incorrect conclusions, too.

Most of the modern authors avoid the use of absolute indicators for studying the changes of non-conformance costs. For that purpose they prefer to use the share or the percent of the investigated costs compared to an advance selected base with a causal link between them. The indicators which the authors most frequently select to carry out analyses in the investigated trend are summarized in table 1.
Most frequently used in literature relative indicators for comparing the costs of non-conformance which originated in different periods of time

<table>
<thead>
<tr>
<th>Authors</th>
<th>Selected indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knyazyuk (2011), Modrak (2007)</td>
<td>Relative share/percent of costs of non-conformance compared to the company’s total costs</td>
</tr>
<tr>
<td>Sailaja, Basak and Viswanadhan (2015), Rajeev (2013), Shulepova and Morozova (2012)</td>
<td>Percent of non-conformance costs compared to the sales made in the relevant period</td>
</tr>
<tr>
<td>Russel and Taylor (1999)</td>
<td>Percent of non-conformance costs compared to company’s production costs</td>
</tr>
<tr>
<td>Antonaras, Memtsa and Iacovidou (2010)</td>
<td>Percent of non-conformance costs compared to all quality costs</td>
</tr>
</tbody>
</table>

We also believe that using the relative indicators guarantees better comparability of investigated costs in different periods of company operation. Since both the numerator and denominator of the represented correlations carry in them the existing inflation in the country for the respective year, its impact is eliminated. Furthermore, the non-conformance costs are bound to company operation at every covered in the report period, which overcomes the main problem leading to misstatements when using the absolute indicators.

However, we think that the bases selected in respect of the designated indicators in table 1, are appropriate to be further refined. For example, Knyazyuk (2011) suggests that the relative share of non-conformance costs compared to the total level of company costs should be used as a monitoring value. However, the latter comprises both the operating costs and financial and additional costs. Whereas the additional costs however, may have certain bearing to contingent non-conformities, the financial ones are not related in any way to their emergence. But their amount may vary considerably over the years and distort the results of the completed statements. Their rise, for example, would increase the value of the denominator in the calculated indicator which would automatically cause a fall in its impact for the respective year. The conclusions which would misleadingly be drawn would be that the costs of non-conformance are reduced because of the specific measures undertaken in the period for their reduction which would mislead the company management team.

The second most frequently used indicator in literature monitors the percent of the investigated costs compared to the value of the production sold for the respective
period. The main problem noted in that case is caused by the fact that only the external non-conformance costs are bound to the volume of completed sales. The internal non-conformance costs originate in the process of manufacture and if at a certain period of time the company has mainly sold stocked in the warehouse production which was manufactured in previous years, reasons for doubts about the accuracy of the proposed indicator emerge again. The arguments concerning the used by Russel and Taylor (1999) “percent of non-conformance costs compared to company’s production costs” are similar, too. In a similar way the external costs of non-conformance are not related to the company’s manufacturing activity but they are related only to marketing of the finished products. Therefore, we all agree that it is necessary to introduce a differentiated approach when selecting the indicators which monitor the specific non-conformance costs over the years. The funds spent on external non-compliances have to be related to the sales completed in the period whereas the ones connected to internal non-conformance – to the volume of finished goods expressed in value terms.

The indicators used in scientific literature possess one additional drawback. Since they are calculated as a share or percent compared to the specific base, the indicators cannot give information about the particular savings of funds achieved after the certain measures have been taken, in that case after the implementation and functioning of QMS. We consider it more appropriate to establish their level for 100 levs manufactured, respectively sold production rather than looking for the percentage between the specific non-conformance costs and the selected adequate base. Thus, instead of defining the percentage points of changed non-conformance costs, we could assert the amount of funds savings that originated concerning the specific expenditure at every 100 levs manufactured production or marketed goods.

We also believe that the analysis allows a deeper exploration of the problem and more profound monitoring of the specific internal and external non-conformance costs. It is possible to establish the impact of the quality management system on every element of the investigated costs.

On the basis of the completed critical analysis and considerations, we believe that, in order to establish the contribution of the implemented QMS for reducing the particular non-conformance costs, it is appropriate to use the indicators, presented in table 2.
## Indicators for monitoring the impact of the implemented QMS on company non-conformance costs

<table>
<thead>
<tr>
<th>Analysed costs</th>
<th>Indicator</th>
<th>Method of definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External non-conformance costs</strong></td>
<td>Level of costs for claims at 100 BGN sales ( (LC_{C100i}) )</td>
<td>[ LC_{C100i} = \frac{C_{Ci} \times 100}{In_i} ] (1) [\text{where:}] [ C_{Ci} ] – costs for claims in year ( i ); [ In_i ] – income from sales of goods in year ( i ).</td>
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<td></td>
<td>Level of costs for fines, defaults, discounts and damages legally identified at 100 BGN of sales ( (LC_{FDDD100i}) )</td>
<td>[ LC_{FDDD100i} = \frac{C_{FDDD_i} \times 100}{In_i} ] (2) [\text{where:}] [ C_{FDDD_i} ] – costs for fines, defaults, discounts and damages legally identified in year ( i ).</td>
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<td></td>
<td>Level of costs for guarantee maintenance at 100 BGN of sales ( (LC_{GM100i}) )</td>
<td>[ LC_{GM100i} = \frac{C_{GM_i} \times 100}{In_i} ] (3) [\text{where:}] [ C_{GM_i} ] – costs for guarantee maintenance, originated in respect of orders placed in year ( i ).</td>
</tr>
<tr>
<td><strong>Internal costs of non-conformance</strong></td>
<td>Level of costs for waste at 100 BGN goods produced ( LC_{w100i} ).</td>
<td>[ LC_{W100i} = \frac{C_{Wi} \times 100}{C_Pi} ] (4) [\text{where:}] [ C_{Wi} ] - costs for waste, originated in year ( i ); [ C_Pi ] - cost price of goods produced in the period</td>
</tr>
<tr>
<td></td>
<td>Level of costs for re-works and extra monitoring events at 100 BGN produced goods ( LC_{em100i} ).</td>
<td>[ LC_{EM100i} = \frac{C_{EM_i}}{C_Pi} ] (5) [\text{where:}] [ LC_{EM100i} ] – costs for waste originating in year ( i ).</td>
</tr>
</tbody>
</table>
Presented in a similar way, the indicators possess the following advantages:

- They provide the opportunity for detailed analysis of the impact of the implemented QMS on the specific internal and external costs of non-conformance;
- They do not distort their results under the influence of inflation or other variables, which are not related to the investigated problem;
- They are calculated in a relevant way to the situations in which the particular costs might arise;
- They might form the basis for determining the savings of funds which occurred as a result of events and tools of the operating QMS.

A major drawback of the selected indicators is that the set of required data and the estimates based on them are much more labour-consuming compared to the alternatives offered in scientific literature.

The data sources for their calculation prior to QMS implementation tend to be the official accounting system (Profit and Loss Account, turnovers and references in statements of accounts 441, 494, 609, 692, 701), claim reports, fines and defaults, reports for rejected goods and other relevant records kept in the company. After QMS implementation the research is supplied with information by a number of specific quality records which are obligatory maintained by the requirements of BDS EN ISO 9001:2008 – mainly reports which concluded about non-compliant products; registers of expressed claims, fines and defaults, etc.

3. An algorithm for measuring the impact of the implemented quality management system on costs of non-conformance

If we want to define the impact of QMS on costs of non-conformance, it is necessary to monitor and do estimates on the basis of the selected above indicators for two periods – one immediately before the system implementation and for the whole period of its operation by different calendar years.

The indicators’ value in the period before QMS implementation show the results achieved by the company in its attempts to reduce non-conformance costs until the moment the decision to implement the quality system has been taken. They provide a benchmark and operate as a point of reference for monitoring its impact on the investigated undesirable costs. Comparing to them the indicators’ significance in the period after the introduction of the standards of The Bulgarian Institute for Standardization БДС EN ISO 9001:2008, conclusions can be drawn whether QMS managed to
lead to an extra reduction of external and internal non-conformance costs. On the basis of a number of estimates the particular funds savings can be determined, which were achieved in the investigated trend after implementing the system.

In this context we believe that measuring the impact of the implemented QMS on external and internal costs of non-conformance can be accomplished by gradually taking the following steps:

1) Calculating the values of the indicators displayed in table 2 for a period of five years prior to the system implementation and for the whole period after its certification (or a specific part of it, in compliance with the requirements of the company managers). The time frame of five years should be selected as a base period for comparison because of its sufficient length to eliminate the influence of random factors and, at the same time compact enough to report on the achieved company experience in the measures to cope with external and internal non-conformances.

2) Monitoring the change of the calculated indicators, looking for trends in their manifestation. It is determined whether for the period after QMS implementation there is a reduction of specific non-conformance costs at 100 BGN manufactured, respectively sold goods, compared both to the above studied five-year period and to the different years of system operation. Depending on the specific numbers conclusions are drawn about the way the company consistently and permanently managed to influence the investigated costs through QMS tools.

3) Determining the savings of the specific costs of non-conformance at 100 BGN manufactured and sold goods by the year of system operation compared to the period of its implementation. What is used as base value of indicators is the average chronological value of the meanings of the particular indicators during the five years immediately after the system certification. If, however, even at the stage prior to system implementation, an explicit tendency for reducing the levels of the investigated costs is determined, it is advisable to use the meanings of indicators for the year immediately prior to the adoption of standards of BDS EN ISO 9001:2008. This is because they give an account of the latest achievements of the company in its efforts to reduce the costs of non-conformance.

The savings of the particular non-conformance costs which are achieved at 100 BGN manufactured production, respectively sales after QMS implementation are defined as follows:
\[ SC_{C100i} = LC_{c100i} - LC_{c100b} \]  (6)
\[ SC_{FDDD100i} = LC_{FDDD100i} - LC_{FDDD100b} \]  (7)
\[ SC_{GM100i} = LC_{GM100i} - LC_{GM100b} \]  (8)
\[ SC_{W100i} = LC_{W100i} - LC_{W100b} \]  (9)
\[ SC_{EM100i} = LC_{EM100i} - LC_{EM100b} \]  (10)

where:

\[ SC_{C100i} \] – savings of costs for claims at 100 BGN sales for different years of QMS operation;

\[ SC_{FDDD100i} \] – savings of costs for fines, defaults, discounts and damages, legally stated at 100 BGN sales for different years of QMS operation;

\[ SC_{GM100i} \] – savings of costs for guarantee maintenance at 100 BGN sales for different years of QMS operation;

\[ SC_{W100i} \] - savings of costs for waste at 100 BGN manufactured goods for different years of QMS operation;

\[ SC_{EM100i} \] – savings of costs for rework and extra monitoring events at 100 BGN manufactured goods for different years of QMS operation;

\[ LC_{c100b} , LC_{FDDD100b} , LC_{GM100b} , LC_{W100b} , LC_{EM100b} \] - over the basis indicators value for the period prior to QMS implementation dependent on the established direction of their development;

\[ i \] - consecutive year in the studied period;

\[ i \geq 6 \], at a studied period of five years prior to QMS certification.

4) Defining the actual savings of specific non-conformance costs in the period after QMS implementation. For this purpose a recalculation is done for the implemented reduction of studied costs by different years for the whole volume of manufactured respectively sold goods:

\[ SC_{Ci} = \frac{SC_{C100i} * In_i}{100} \]  (11)
\[ SC_{FDDD} = \frac{SC_{FDDD100i} * In_i}{100} \]  (12)

\[ SC_{GMi} = \frac{SC_{GM100i} \times In_i}{100} \]  \hspace{1cm} (13)

\[ SC_{Wi} = \frac{SC_{W100i} \times In_i}{100} \]  \hspace{1cm} (14)

\[ SC_{EMi} = \frac{SC_{EM100i} \times In_i}{100} \]  \hspace{1cm} (15)

where:

- \( SC_{Gi} \), \( SC_{FDDDi} \), \( SC_{GMi} \), \( SC_{Wi} \), \( SC_{EMi} \) – actual saving of specific non-conformance costs in different years of QMS functioning:
  \( i \geq 6 \), at studied period of five years prior to QMS certification.

The indicators in this group reflect the additional costs for specific non-compliances which the company might fulfill if the same amount of production was manufactured in the conditions prior to QMS implementation, but, currently it has saved them.

5) Determining the total savings of costs of non-conformance \( (SC_i) \), achieved after the QMS implementation by different years of its functioning.

\[ SC_i = SC_{Ci} + SC_{FDDDi} + SC_{GMi} + SC_{Wi} + SC_{EMi} \]  \hspace{1cm} (16)

where:

- \( i \) - consecutive year in the studied period;
- \( i \geq 6 \), at a studied period of five years prior to QMS certification.

On the basis of the completed estimates by different years of QMS functioning we can judge whether the system after applying its instruments, managed to cause a permanent reduction of non-conformance costs and what funds are saved to the company by using its instruments. In general, all values of \( (SC_i) \), greater than zero attest the presence of fulfilled savings in the respective calendar year. In order to draw the conclusion that QMS has had a significant impact on the level of non-conformance costs it is required that a permanent tendency should be established for generating such savings in the whole period of QMS operation. Otherwise, we can only talk about reducing the investigated costs, which was generated by random factors.
Conclusion

Measuring the impact of the implemented and operating quality management system on the costs of non-conformance has a major significance for every organization looking for efficiency. The algorithm which was looked at provides a possibility to monitor the changes which have occurred in the level of costs for internal and external non-conformances caused by the QMS implementation, and calculating the achieved savings as results in the researched trend. The information obtained can be used successfully by the company’s senior management for performing subsequent estimates about the efficiency and effectiveness of the implemented system.

However, it is necessary to pay attention on the fact that the QMS has the potential to reduce the non-conformance costs, aiming at the reasons for their occurrence only if it was effectively implemented. If the company resorts to adoption of BDS EN ISO 9001:2008 only for the sake of the certificate the system could not be expected to bring about a significant reduction of funds spent in this direction.

The implementation of the proposed algorithm and of all future estimates concerning the evaluation of QMS could be made significantly easier if company’s key quality records are integrated in the accounting software which was made use of. Thus, the values of the integrators looked for by the management will be worked out automatically without time and efforts lost in collecting data and doing calculations.

References

EVALUATION OF FREE CRM SOLUTIONS FOR SMALL E-BUSINESS OPERATIONS IN BULGARIA

Bozhana IVANOVA¹

Abstract

CRM plays a key role in the development of e-commerce. Online retailers, owners of small online stores cannot afford expensive CRM systems, so it is necessary to apply a method for evaluation of free CRM solutions available on the market. The present article offers a comparative analysis of free CRM systems, based upon an own system of evaluation criteria. A solution applicable to small online stores in Bulgaria is being suggested.

Introduction

Customer satisfaction is a major factor in the development of e-commerce and a guarantee for a growing public interest in it. Changes in customer needs are seen as crucial for the e-business sector thus placing a special emphasis on the management of customer relationships (CRM) and the way it could be further improved.

In Bulgaria, the CRM systems are not so popular which creates opportunities for the development of a potential niche market in the future. If implemented in small e-stores¹ throughout the country, CRM software will be able to significantly help their market operations and ensure longer viability and future demand.

In view of the above, the purpose of the present article is to justify the need to implement a CRM software in small e-store operations in Bulgaria and to propose adequate evaluation and selection criteria towards a free CRM solution. To achieve the above goal, we shall discuss the basic features of CRM systems and their use in on-line trade activities, and we shall compare some of the free software solutions that are applicable to small e-stores but also present new options for improvement of customer relationship management in terms of e-commerce in the country.

Indeed, similar research has been done by scientists in other countries (Bucholtz, n.d.), (Wallen, 2013), (Guay, 2014), (Bdc.ca, 2015), (G2crowd.com, 2015), but due to the relatively low popularity of CRM systems in Bulgaria, none of them is specifically designed around the operations of small e-stores in the country.

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1. Main characteristics of CRM systems used in e-commerce

In specialized literature, customer relationship management (CRM) outside the specific area of application can be defined as a **continuous process** on the strength of which, customer information is transformed into positive relationships with customers (Wittenmann & Ables, 2011, p. 5). CRM strategies are applied to e-trade via the electronic systems for customer relationship management (or e-CRM systems, also called “CRM systems“, seen as their derivative). Every e-store interacts with a number of external systems (Ruskov), which are used to handle the business processes of on-line vendors, the CRM system being one of them (see fig. 1).

**Fig. 1. E-store relationships with external systems needed to sustain its operations**

CRM systems can be seen as a combination of operating and analytical software where the operational software serves to extract and store data collected on customers, markets etc., whereas the analytical software serves to process data collected, different techniques for market segmentation, and compare data and reading protocols. The functional framework of CRM systems can be defined in relation to the following areas: **marketing, sales, service, strategies and analysis**.

CRM solutions that are applicable to e-store operations shall integrate features such as managing advertising campaigns, cross sells and multi-channel marketing.
For the purpose of processing orders, CRM systems need to integrate tools for control over service efficiency that are capable of automating and shortening the sale cycle.

Among key CRM system functions we shall highlight the following: managing customer databases and interfacing data received through available communication channels with a specific client’s profile, not to mention that accurate customer data is seen as crucial in building CRM strategies. Of key importance for e-store operations and their success is the integration of a package that helps manage and effectively track relationships with key business partners and maintain business contacts on a long-term basis.

**CRM plays a key role in e-commerce** as it helps improve customer service and quality of service which gives us reasons to believe that existence of small e-stores on the on-line market is directly related to CRM system integration. CRM software is of crucial importance for the development of e-commerce although its role has not been fully recognized by on-line vendors in Bulgaria – only 4% of the hundred leading retailers are using CRM software (Балкан Сървисис, 2015). Despite existing problems and limitations, raising awareness of the need to implement CRM systems in the operations of small e-stores in Bulgaria, can be seen as an important step in managing customer relationship and e-commerce as a whole.

Faced with a number of problems such as raising start-up capital, lack of necessary staff capacity, concerns about covering expenses and return on investment within short periods, and limited interest on the part of foreign investors due to high risk, on-line vendors operating small e-stores cannot afford to buy a paid CRM solution which is a hitch in managing their customer relationships properly.

**Problems with CRM, arising from the business external environment** are as follows: finding customers and keeping them on a long-term basis, adapting the product portfolio to the dynamic changes in customer preferences and interests, building e-store social profile or brand and maintaining it in order to help win over customers trust and loyalty.

**Problems with CRM arising from the business internal environment** are mainly associated with the provision of a quality service (recruitment of qualified staff can be hard if company resources are limited), loss of information in the process of communication with customers, etc.

The outlined problems with CRM often arising from the inability of on-line vendors to purchase and integrate a paid CRM software are indicative of the need to improve management of customer relationship in terms of small e-store operations in Bulgaria.

Under conditions of financial instability, the owners/operators of small e-stores are experiencing a number of problems which encumber integration of CRM software
in their e-stores. An independent survey conducted at the end of 2014 in Bulgaria shows that among the top 6,500 revenue generating companies, representing 58 of the leading industries in the country, less than 10% have an integrated CRM system (CBN Pannoff, Stoytcheff & Co., 2014). And out of the 125 leading companies, only 6% can boast a working software for managing customer relationships. In comparison, in most European countries the percentage of companies using CRM solutions for their operations is 28% (Eurostat, 2015). This is indicative of the extremely low popularity of CRM systems in Bulgaria which could be attributed to the impact of certain factors acting as deterrents to the initiation and approbation of innovations. The most difficult to overcome is that the price of today’s complex CRM systems often goes over the budget of small e-stores (see Table 1). A 2013 survey shows that only 12% of respondents are prepared to invest in a CRM system providing they are not backed by an EU funded project. (ФТС България, 2013).

Table 1

<table>
<thead>
<tr>
<th>Monthly costs incurred by using paid CRM systems (CRM Switch, 2013)²</th>
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<tbody>
<tr>
<td>Salesforce</td>
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<tr>
<td>Performance</td>
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<td>Enterprise</td>
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<td>Professional</td>
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</table>

CRM software has limited popularity among on-line operators or vendors in Bulgaria which can be explained with the fact that they lack the resource and capital to invest in software development and CRM software in particular. Access to paid CRM solutions developed by leading publishers of CRM software is expensive and hard to fit into the limited budget of small e-store operators which in turn, hinders development of customer relationship management. As earlier mentioned, only 12% of the companies are prepared to invest in a CRM system, while using data from the same survey, 76% of respondents believe that integration of a CRM system in their business operations will give them a competitive edge. In this line, we can say that development of CRM in Bulgaria can be driven by the implementation of a free software satisfying the needs of small on-line operators of e-stores.

Having discussed the need for a simple free CRM solution for on-line operators of small e-stores in Bulgaria, we shall further discuss certain systems that can match the scale and specific nature of their business.
As free versions of CRM systems are often confused with the open source systems, it is important to draw a line and highlight differences between these two software types.

A free CRM solution is the one which does not involve any charges for the acquisition, installation, integration and functioning of the application, (Meeker, 2008, p. 21 – 22).

Solutions of the open source type give users access to the code and freedom to modify it, but this does not necessarily mean that the software comes free and that its software developers will maintain and develop it free of charge (Opensource.com, n.d.).

Therefore, having in mind the limited budget of small e-store operators in the country, we can opt for the free CRM software as a suitable solution to serve the purposes of managing customer relationships. This definition covers the following types of software solutions – free CRM systems, limited CRM systems and adapted solutions³.

- **Free CRM systems** are those that can be stored on a server – property of the CRM supplier, or a server purchased from an on-line vendor.

- **The first type** is a web-based hosted software, which cannot be accessed by the e-store operator. Its major disadvantages are related to data security, service reliability and poor maintenance.

- **The second type** of free CRM systems represents web-based hosted applications purchased by the vendor. With this type of system, the on-line retailer has the freedom to make adjustments to the code and the way the system functions. This type helps avoid certain problems with data security and leads to a better efficiency, since high level of security is a major requirement in the realization of buying and selling on-line (Iliiev, 2011, p. 33 – 35). And as Bulgarian clients are still suspicious about Internet sites specializing in e-commerce, we think that web-based, hosted CRM solutions can come in handy.

- **Limited software** – this type of solutions offer limited possibilities to on-line retailers in its free version. One of the weaknesses is seen in the limited number of users that can use the system.

- **Adapted solutions** – software solutions that are adapted/customized and used by the on-line retailer for the purposes of CRM. Thus for example, electronic tables in MS Excel, Google Sheets and others can be used as data bases for gathering information on consumers. Their shortcomings relate to the need of preliminary adaptation to the activities of e-stores/ e-store operations and their limited functionality as they provide a software operation only partially.
2. Evaluation of free CRM solutions

On-line retailers lack competence in the area of free solutions which makes their choice difficult. They are not familiar with systems offered on the software market and their characteristics. A solution within a given functional range may be appropriate for one owner of a small on-line store in terms of the specific needs of the business but it does not make it a universal solution. Thus for example, while a given CRM system offers advanced capabilities for sales management another CRM can be better developed for software support of marketing activities, which discourages on-line retailers and confuses their choice.

Thus, we arrive at the conclusion that it is necessary to establish a system of criteria which is to provide the evaluation basis for available free CRM solutions and help small e-store owners to get easily orientated and find a solution that best meets their individual needs. Evaluation criteria can be much more precise and detailed but as our analysis is not aimed at developing a CRM software but to ease on-line retailers in their choice, we think that if we break down the terms of comparison in the following groups, they can be comprehensive enough to meet this goal:

- **Software coverage** – evaluates system coverage in terms of sales management, marketing activities, etc.
- **Extended features** – defines the scope of functions which can be used by employees of e-stores to facilitate their work processes, including features such as the ability to extract reports with variable structure, create forms and others.
- **Social engagement** – evaluates possibilities to integrate with social networks, which is of prime importance for the operations of small e-stores as it multiplies communication channels.
- **Technologies** – reflects an aggregate of technical aspects such as type of hosting, database, etc.
- **Integration** – shows features for system integration with some of the most commonly used software products by on-line retailers such as e-mail clients and others.
- **Customer support** – it focuses on a set of tools which will help ensure customer support.

In order to achieve more clarity in order to decide to what extent free CRM solutions help the work processes of small e-stores, we formulated evaluation criteria (grouped under the functional headings above) and compared their capabilities (see Table 2). Pooled data are based on the results of some of the most
popular and efficient free CRM systems on the software market in the last years, according to a number of studies in this area. (Bucholtz, n.d.), (Wallen, 2013), (Guay, 2014), (Bdc.ca, 2015), (G2crowd.com, 2015).

**Table 2**

Comparing the capabilities of free CRM systems

<table>
<thead>
<tr>
<th>№</th>
<th>Criterion</th>
<th>Civi CRM</th>
<th>Concur- sive</th>
<th>Open Taps</th>
<th>Splendid- CRM</th>
<th>Sugar- CRM</th>
<th>vTiger</th>
<th>XRMS</th>
<th>Xtuple</th>
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<td>I</td>
<td>Software coverage</td>
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<td>Managing partner relationships</td>
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<td>II</td>
<td>Extended features</td>
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<td>Management boards</td>
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<td>Data warehouses and on-line analytical processing of data (OLAP)</td>
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<td>Reports with variable structure</td>
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<td>Form building tools</td>
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<td>Design tools for work processes</td>
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<td>III</td>
<td>Social activity</td>
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<td>1</td>
<td>Creating vendor or on-line retailer portal</td>
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<td>Capabilities to create a third-party portal</td>
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### IV Technologies

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<tbody>
<tr>
<td>3</td>
<td>Integration with social networks</td>
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<td>4</td>
<td>LAMP</td>
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<td>5</td>
<td>SQL</td>
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<td>6</td>
<td>MySQL Server</td>
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<td>7</td>
<td>Oracle RDBMS</td>
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### V Integration

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<tbody>
<tr>
<td>1</td>
<td>Outlook</td>
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<tr>
<td>3</td>
<td>Google Mail/Calendar</td>
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<td>4</td>
<td>iPhone synchronization</td>
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<td>5</td>
<td>Android synchronization</td>
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<td>6</td>
<td>Integration with ERP packages</td>
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### VI Customer support

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<tbody>
<tr>
<td>1</td>
<td>Help Desk</td>
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<td>2</td>
<td>24/7 customer support</td>
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### Legend:

- □ Functionality is not supported/maintained?
- □ Functionality is partly supported
- ▪ Functionality is kept

In the first criteria group, under the heading ‘**Software coverage**,’ the scores are almost similar. Of lower standing are OpenTaps and XRMS, while the least supported criteria in the group is that of Partner Relationship Management.

In view of the criteria in the **Extended features** group, CiviCRM and XRMS exhibit weaker capabilities, especially in relation to data warehouses and on-line
analytical processing of data, generation of report with variable structure and form building tools (drag and drop form builder). The remaining products meet the criteria with relatively similar or approximating scores.

In terms of criteria regarding **Social Engagement**, two of the products stand out with very good support, namely Concursive and SugarCRM (Community Edition). Integration with social networks is one of the major significance criteria when choosing a CRM system for small e-store operations. OpenTaps and XRMS products however, fail to demonstrate strong capabilities in this group which automatically excludes them as a possible choice for a CRM solution that can be applied in small e-store operations.

In the fourth criteria group entitled **Technologies**, Compiere and Xtuple are among the solutions with the least capabilities. Offering the product as a service, maintaining SQL and MySQL Server, and storing the retailer hosting are criteria supported by only three products. These are SugarCRM, Splendid CRM and XRMS.

The fifth criteria group called **Integration** is of extreme significance for the running of work processes of small e-stores, including work with an e-mail client, integration with ERP packages, etc. CiviCRM and XRMS are among applications exhibiting poor capabilities while Splendid CRM and Xtuple tend to demonstrate a better degree of integration.

The last criteria group **Customer Support** also plays a key role in CRM systems finding application in e-commerce. Here, the only possible solution meeting both criteria is SugarCRM.

In view of the comparative analysis based on own system of evaluation criteria organized under different headings for developing free CRM systems potential, it becomes possible to outline the following main features: integration with social networks and external systems and applications needed in the work of on-line retailers; use of a wider range of tools to manage customer data; generation of queries, reports and forms. From collected data we can draw the conclusion that no free CRM solution is able to meet all the above criteria. Indeed, systems developed for one functional area tend to exhibit faults in another which prevented us from finding a universal solution to be adopted by all small e-stores. Nevertheless, the proposed system of evaluation criteria can be used to guide on-line retailers/vendors in their choice of a free CRM software.

Notwithstanding the above outlined areas of improvement, free CRM software remains a viable solution for on-line retailers and owners of small e-stores, therefore in view of the tested indicators we have grounds to conclude that SugarCRM Community Edition is the software with better capabilities than other available free software systems.
Conclusion

In the present article we have discussed the concept of CRM systems and their implications and significance for e-commerce operations. Also, we have outlined some of the problems which owners of small e-stores in Bulgaria have been faced with and pointed to the need of implementing free software solutions. On the basis of a comparative analysis using a system of evaluation criteria classified under six major groups, we were able to identify the main strengths and weaknesses of free CRM solutions available on the market today. In relation to the CRM systems that can be implemented for small e-stores operations in Bulgaria we can recommend the use of SugarCRM Community Edition in combination with some extra applications orientated towards on-line vendors and their needs which go outside the scope of the system, in the form of tailor-made solutions. The above solution is seen as suitable for the operations of small e-stores in Bulgaria.

In view of analysis conducted on free CRM systems we arrived at conclusions that might help on-line retailers in their choice of solutions applicable to the scope and specific needs of small e-store operations.

Being aware of CRM and its significance for small on-line operations, we have reasons to believe that this type of software discussed in the context of e-commerce has a great potential for development in Bulgaria.

End Notes

1. The term ‘small e-store’ is not commonly used or explicitly defined. The present article focuses on a type of e-store characterized by an annual income below 50 000 BGN, staff employed – around 15 or less and number of product portfolio items – up to 4000.
2. The above data reflect the prices of different versions of CRM systems (Salesforce, Microsoft Dynamics CRM and SAP) per month for 1 user.
3. By “adapted solutions” we shall understand software products, whose functionality could be adapted and applied for the purposes of CRM in the operations of small e-stores.

References

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