QoS versus QoE for Database Tuning

Jaroslaw Kurpanik, Malgorzata Pankowska
Department of Informatics
University of Economics in Katowice
Email: jaroslaw.kurpanik@ue.katowice.pl, pank@ue.katowice.pl

***Abstract*—Quality in Information Communication Technology (ICT) domain is understood as the totality of characteristics of an entity that are important for its ability to satisfy users. In the paper, authors present a consistent set of concepts concerning Quality of Experience (QoE) and Quality of Service (QoS) modelling for information system development. In the last part, they focus on database application tuning and give an example of how the selected QoS measures (i.e., Cost, %CPU and physical read) can be used for quality improvement.**

Keywords-QoE, QoS, quality measures, quality management, database tuning.

I. Introduction

Last years developed servitization is considered as a business strategy to get competitive advantage in IT sector. Servitization as a process is developed within Service Science, which is an interdisciplinary approach to study, create, improve a service [1]. The generic model of services process lifecycle is argued to be derived from the basic phases of a generic business process lifecycle and encompasses part of the possible service outcomes, captured in the Interact-Service-Propose-Agree-Realize (ISPAR) model [2]. In services, values are co-created by user and service provider. Value is determined by results, quality of the customer experience, service price and access costs. Service has a different meanings in different disciplines. In information systems engineering, the service concept is used to separate the external and internal behaviour of a system. In enterprise architecture approach, service is perceived a bidge that different layers of an enterprise [3].

In the paper, servitization is assumed to include all the activities for Information Communication Technology (ICT) services and application quality management. The paper aims to emphasize the relations, differences and applicability of Quality of Experience (QoE) and Quality of Service (QoS) for business application development. The first part of the paper covers explanation of QoE and QoS in the ICT sector. The second part includes discussion on usage of QoS approach for tuning the databases for business.

II. QoS versus QoE

The quality management is to maintain the internal quality of an entity. In order to achieve this, it aims at four subjects, i.e., the product quality, the process quality, the ICT facilities quality and the business organization quality, mostly aiming at matters like quality of people and their expertise and competencies.

According to Deora et al. [4], quality can be perceived in different aspects, i.e., quality as functionality, as reputation, and as conformance, which is synonymous with meeting specifications. These different views require quality to be monitored and measured differently. Quality as a functionality characterizes, for example, the design of a software and can be measured by comparing the piece of software against others offering similar functionalities. Quality as conformance is monitored for each software individually, and usually requires the user's experience in order to measure the promise and expectations against the delivery. Quality as reputation means that evaluated software is regarded as a reference over time because of its functionalities and conformance qualities. Beyond that quality can be considered as a continuous improvement of non-functional features and can be measures by comparing the modified software against the same piece of software before modification, assuming it keeps the same functionalities. Considering service quality means to focus on the gaps that infuence the service quality. At first, the expected service as perceived by the service provider is different from what is expected by the customer. Second, the service specification as used by the service provider differs from the expected service as perceived by the service provider. Third, the actual service delivery differs from the specified services, because of the deficiencies in human resource policies, and failures to match demand and supply. Fourth, communication about the service does not match the actual service delivery because of ineffective management of customer expectations, overpromising, and inadequate horizontal communications. Fifth, the actual service performance differs from the customers' expectations [15].

Service quality as an intangible characteristics is expressed by other qualitative characteristics:

- reliability, understood as the ability of a service operation to be executed within the maximum expected time frame,
- response time to handle the user requests,
- availability, understood as the probability for a service being accessed properly in an observation period,
- integrity, understood as the quality aspect of how the service maintains the correctness of the interaction in respect to the source.

 ISBN: 978-1-61208-416-9

According to ISO 9000:2000, quality is the ability of a set of inherent characteristics of a product, system or process to fulfill the requirements of customers and other interested parties. Nowadays, researchers and practitioners differentiate QoE from QoS. The relationship between these two concepts are formulated in different ways:

- QoE as a counterbalance form for QoS.
- QoE as a contradiction of QoS.
- QoE as a linear combination of QoS and user experience.
- QoE as an interchangeable concept of QoS.

The first approach emphasizes the user's perceptions and experiences. Therefore, the service providers are requested to deliver the software and services not with a high QoS, but with a high QoE to their customers [6].

The QoE concept is particularly important for human-machine interface design, where there is a focus shift from classical usability, understood in terms of effectiveness and efficiency, towards the design of experiences that people have through the use of the interfaces. QoE is defined as the degree of delight or annoyance of a person whose experiencing involves an application, service, or system. It results from the person's evaluation of the fulfilment of their expectations and needs with respect to the utility and/or enjoyment in the light of the person's context, personality and current state [7]. QoE means the overall acceptability of an application or service, as perceived subjectively by the end user and QoE is supplemented by QoS, which means totality of characteristics of a service that bear on its ability to satisfy stated and implied needs of the user of service.

In the second approach, Varela et al. [8] contrast QoE with QoS. According to them, QoS means the totality of characteristics of a telecommunication services, but QoE is not limited to only such services. QoE is defined entirely from the user's perspective. In QoS evaluation process, the focus is mostly on performance of telecommunication systems, while QoE focuses on ICT services and applications. For QoS evaluation, methods are technology oriented, empirical and include simulation results' measurements. QoE evaluation is a multi-disciplinary and multi-methodological approach. In this contradictive process, Weiss et al. [9] add that QoE itself is an important measure for addressing the instantaneous user reaction to changes in the QoS (e.g., types of transmission degradations). Assessment methods of momentary QoE include the measures for truly instantaneous assessment, but also the assessment for short-term samples which exhibit microscopic variation [9].

For Garcia et al. [10], QoE is influenced by user expectations, context and personal preferences. The perception and understanding of the users' QoS are typical for video quality evaluation, but they are going beyond purely measuring video quality. They cover new subjective studies and methodologies for episodic subjective quality evaluation in realistic environments. The quality of the multimedia content as perceived by the user is referred by Timmerer et al. [11] as an example of QoE application. As such, the QoE is defined for a certain modality (e.g., image) or simply for a combination of audio and visual elements and QoE is targeting two human senses, namely hearing and seeing. They argue that browsing multimedia content may also stimulate other senses such as olfaction, mechanoreception, equilibrioception, or thermoreception. Users are located in a certain environment, where there are other sensory information, e.g., light, wind, vibration, and scent, so the users perceive also these additional sensory effects and even consider them as a part of the particular multimedia content and enrich their personal experience. Therefore, although there is a wide range of factors influencing user experience and QoE, the most important factors can be classified into three main categories; the context around the user, the user's state, and the system properties [7].

Reiter et al., specify ten context categories as follows: personal context, social context concerning interpersonal action and relations, economic context including cost and brand of software applications, event-based context, application based context, historical context, physical context describing the user locations and movements, temporal context, task context, and technical context. The task context concerns the user activities realized in parallel or as a sequence, and interruptions. The technical context describes the relationships among the system of interest and other relevant devices, applications, networks and other informational artefacts [12].

In the third approach, QoS deals with the performance aspects of physical systems. QoE deals with the users' assessment of system performance, as colored by context, culture, the users' expectations with respect to the system or service and their fulfilment, socio-economic issues, and psychological profiles, among other factors.

According to Beyer and Moller [13], QoE is defined as weighted linear combination of QoS and user experience. For Wennerheimer and Robinson, there is no simple correlation of QoE and QoS [14]. However, a generic correlation model between QoS and QoE does not lead to any improvements. QoE is the overall acceptability of an application or service and as such QoE represents user satisfaction. From the software developer point of view, QoS is the collective effect of software usability and service performance. Therefore, QoE covers nontechnical and human aspects of system performance, i.e., smoothness and interaction maintenance effort, response ability, pace, naturalness, comprehensibility effort, accessibility, integrity, retainability, ergonomics, aesthetics, learnability, intuitivity, and intrinsic motivation of user activity.

The aesthetics is connected with ICT devices parameters concerning resolution, colour brightness, noisiness, loudness, and vibration. QoS concerns the usability of functionalities of software, services and devices. Apart from that, QoS properties, such as performance and reliability are increasingly important to ensure user acceptance.

Generally, QoS parameters can be classified as stimulants and destimulants [15]. Stimulants are variables, which values should be increased for the quality improvement, as it is in the case of reliability, compatibility, interoperability, scalability, effectiveness, efficiency, security, accuracy, coherence, and network throughput.

 ISBN: 978-1-61208-416-9

Destimulants are QoS parameters, which values ought to be decreased in the quality improvement process, as it is in the case of metrics including time delay, jitter, interruptions, errors, discontinuity, response time, packet loss rate, latency and time to repair.

QoS is determined in relation to the fulfilment of the service agreement. The measurement of the QoS needs to take into consideration the input from both the customer as well as the service provider, as the service and software development agreement binds both parties. Measuring the quality of software and services is important in modern service-oriented environments. It is reshaping the world of business by providing trusted business processes and the reputation of service providers and software developers. The QoS characteristics are a quantifiable aspect of QoS and they are developed independently of the means by which they are represented and controlled. The values of QoS characteristics include not only numbers (e.g., Booleans, integers, reals, complex numbers), but also vectors, matrices, ranks and names of states.

Particularly in the ICT sector, the subclasses describing QoS characteristics of general importance to communication and processing are presented by the following characteristics groups: time-related, coherence, capacity, integrity, safety, security. QoS characteristics cover not only metrics, but also policies, which make a concrete software useful.

The policies include scheduling and dispatching policies, admission control of requests, levels of services supported in the server, and management of service requests.

In the last, fourth approach, QoE and QoS terminology are used interchangeably [16]. QoE is the overall performance of a system from the point of view of the users. QoE is a measure of end-to-end performance at the service level from the user perspective and an indication of how well the system meets the user's needs. QoS is a measure of performance from the network perspective. QoS refers to a set of technologies that enable the network administrator to manage the effects of congestion on application performance as well as providing differentiated services to selected network traffic flows or to selected users. Quality management in ICT sector supported by QoS characteristics requires establishing, monitoring and maintenance of the actual QoS characteristics, controlling of the QoS targets, alerting as a result of some events relating to the QoS management [17].

III. QoE Application Example

Top management and company decision makers have an opportunity to measure the quality of ICT services with Information Technology Service Management (ITSM) system. Therefore, they are able to manage business processes and technologies. ITSM system enables ICT providers to adhere to the conditions included in the Service Level Agreement (SLA), expressed by Key Performance Indicators (KPIs). Usually, the SLA must contain quantitative measures that represent a desired and mutually agreed state of a service, provide additional boundaries of a service scope, and describe guaranteed minimal service performance [18].

Furthermore, KPIs are metrics that are used to measure efficiency and effectiveness of a service, and service operation status. The SLA examples would cover, for a particular customer, the reaction time, resolution time, compliance to agreed deadlines. KPIs examples could include average reaction time by users, incoming ticket volume trend, time of system inaccessibility, number of solved problems in an established time, number of correctly provided services in relation to the number of all services.

However, service catalogue is constructed in the context of particular business goals' specification. ICT service design does not concern the whole system in the same way. The quality parameters may be not defined for database, application servers or networks. The quality parameters are defined for particular levels of the information system. They are analysed and maintained inside the ICT department, which focuses on the new solution development, as well as on the existing functionalities extension. However, this approach is not appropriate for business, which requires the effects important for the customers. Therefore, the accountability of ICT services should be based on SLA parameters.

For example, in an information system for sale and distribution, number of cases of exceeding the accepted time (i.e., 2 seconds) for registration of one item in an order during a day. User receives a phone request and inserts data, which are dictated by their customer. Average number of items dictated through the phone covers about 70 elements per one customer request. Request reception time is critical. After the registration of each item in request, information systems verifies product accessibility, controls the product promotions and calculates the price and margins. Information system is to measure the time between product approval and the moment of the presentation of all data on the terminal screen. In case of exceeding the time, the information is registered in log file. Business user accepts no more than 50 cases, where the time of 2 seconds is exceeded. Logs are constantly monitored and in a situation of increasing the number of such cases, suitable actions are undertaken to return to the acceptable level of service. Similar time and acceptance levels are defined by inventory division users working with mobile devices.

IV. QoS Application Example

The consideration on the quality measures refers to the Oracle database efficiency. Efficiency analysis and database tuning requires multidimensional approach, because of the number of influencing variables. For Oracle applications, the database tuning is considered as:

- Good database design and distribution of the database workload across multiple disks to avoid or reduce disk overloading.
- Disk I/O optimization, which is related directly to throughput and scalability.
- Checkpointing to increase the I/O activity and system resource usage.

- Batching multiple operations together and/or increasing the number of operations that run in parallel (increasing concurrency) [19].

In this paper, authors focus on operations, which are important from the point of view of database administrator and which have an impact on database system efficiency and on the speed of query performance. Particularly, they consider input/output (I/O) operations and the number of physical disc readings realized by a database system to find the answer to the user query. If that number is smaller, the waiting time for query results is shorter. The number can be optimized in different ways, for example by suitable index creation [12]. A query execution plan is an ordered set of steps used to access data in an SQL relational database management system.

Query optimizer attempts to determine the most efficient way to execute a given query by considering the possible query plans [20]. They can be rule-based or cost-based. In the first approach, the rule-based optimizer (RBO) chooses an execution plan based on the rules and access paths available and the ranks of these access paths [21].

Oracle's ranking of the access paths is heuristic. If there is more than one way to execute an SQL statement, then the RBO always uses the operation with the lowest rank. Usually, operations of lower rank execute faster than those associated with constructs of higher rank. Cost-based optimizer (CBO) generates a set of potential execution plans for SQL statements, estimates the cost of each plan, calls the plan generator to generate the plan, compares the costs, and chooses the plan with the lowest cost. In this approach the query performance time is estimated for different options and the query for which the time is the shortest is selected [22].

In Oracle, the cost is defined as units of work or resource used. The query optimizer uses disk I/O, CPU usage, and memory usage as units of work. So, the cost used by the query optimizer represents an estimate of the number of disk I/Os and the amount of CPU and memory used in performing an operation. The operation can be scanning a table, accessing rows from a table by using an index, joining two tables together, or sorting a row set [23]. The cost of a query plan is the number of work units that are expected to be incurred when the query is executed and its result produced. The cost of a table scan or a fast full index scan depends on the number of blocks to be scanned and the multiblock read count value. The cost of an index scan depends on the levels in the B-tree, the number of index leaf blocks to be scanned, and the number of rows to be fetched using the rowid in the index keys [7] [18]. Oracle proposes many different indexes applying for minimizing the query performance cost.

Indexes are optional structures associated with tables and clusters. Indexes can be created on one or more columns of a table to speed up SQL statement execution on the table. Indexes are the primary means of reducing disk I/O when properly used. Oracle provides several indexing schemes, e.g.:

- Normal indexes, by default, Oracle Database creates B-tree indexes.
- Reverse indexes.
- Bitmap indexes.

The purpose of an index is to provide pointers to the rows in a table that contain a given key value. In a regular index, this is achieved by storing a list of rowids for each key corresponding to the rows with that key value.

Oracle Database stores each key value repeatedly with each stored rowid. In a bitmap index, a bitmap for each key value is used instead of a list of rowids [24]. Creating reverse key index, compared to a standard index, reverses the bytes of each column indexed (except the rowid) while keeping the column order [11].

In this example, the sh.customers table was used for the verification of impact of indexes applying on the cost of query performance. Before the decision on index creation, certain statistics for sh.customers table were calculated and presented in Table 1.

TABLE I. SEGMENT OF COLLECTED COLUMN STATISTICS

COLUMN_NAME	DENSITY	NUM_NULLS
CUST_CITY_ID	0,00217939065	0
CUST_TOTAL	1,00000000000	0
CUST_STATE_PROVINCE	0,00689655172	0

Table 1 consists of three columns, where the value in "DENSITY" column provides information about the selectiveness of the column. Lower value indicates that the column is a better candidate to create index. Value included in "NUM_NULLS" column indicates how many "null" values are included in the column [11] [18]. The "DENSITY" value for the "CUST_TOTAL" column is equal to 1, so the column contains only one unique value, therefore creating an index on this column is not necessary, because the full table scan can be efficient. For the two other columns, the selectiveness of data is relatively high. Therefore, the columns are good candidates for indexing.

TABLE II. STATISTICS IN THE "WITHOUT INDEX (FULL TABLE SCAN)" CASE

Without index (Full table scan)						
Id	***Operation***	***Name***	***Rows***	***Bytes***	***Cost (%CPU)***	***Time***
0	SELECT STATEMENT		66	990	405 (1)	00:00:01
1	TABLE ACCESS FULL	CUSTO -MERS	66	990	405(1)	00:00:01
28 physical read IO requests 11919360 physical read bytes 28 physical read total IO requests 11919360 physical read total bytes 11 physical read total multi block requests 1455 physical reads 1455 physical reads cache 1427 physical reads prefetch						

TABLE III. STATISTICS IN THE "NORMAL INDEX" CASE

Normal Index						
Id	*Operation*	*Name*	*Rows*	*Bytes*	*Cost (%CPU)*	*Time*
0	SELECT STATEMENT		66	990	24 (0)	00:00:01
1	TABLE ACCESS FULL	CUSTO -MERS	66	990	24 (0)	00:00:01
2	INDEX RANGE SCAN	TEST_ INDEX	23		2(0)	00:00:01
1 physical read IO requests 8192 physical read bytes 1 physical read total IO requests 8192 physical read total bytes 1 physical reads 1 physical reads cache						

TABLE IV. STATISTICS IN THE "REVERSE INDEX" CASE

Reverse Index						
Id	*Operation*	*Name*	*Rows*	*Bytes*	*Cost (%CPU)*	*Time*
0	SELECT STATEMENT		66	990	4543 (1)	00:00:01
1	TABLE ACCESS BY INDEX ROWID	CUSTO -MERS	66	990	4543 (0)	00:00:01
2	INDEX FULL SCAN	TEST_ INDEX	4751		125 (0)	00:00:01
24 physical read IO requests 101580 physical read bytes 14 physical read total IO requests 1015808 physical read total bytes 124 physical reads 124 physical reads cache						

TABLE V. STATISTICS IN THE "BITMAP INDEX" CASE

Bitmap Index						
Id	*Operation*	*Name*	*Rows*	*Bytes*	*Cost (%CPU)*	*Time*
0	SELECT STATEMENT		66	990	17 (0)	00:00:01
1	TABLE ACCESS BY INDEX ROWID	CUSTO -MERS	66	990	17 (0)	00:00:01
2	BITMAP CONVERSION TO ROWIDS					
3	BITMAP INDEX RANGE SCAN	TEST_ INDEX				
160 physical read IO requests 10485760 physical read bytes 160 physical read total IO requests 10485760 physical read total bytes 1280 physical reads 1280 physical reads cache 1120 physical reads cache prefetch 1120 physical reads prefetch warmup						

Tables 2, 3, 4, and 5 cover the plan of performance of the query: select cust_city from sh.customers where cust_city_id is between 52379 and 52383.

Application of indexes influences an increase of central processor unit performance, as well as decreases physical read, total IO requests and cost of operations.

In the "Without index (Full table scan)" case, the Cost (%CPU) is smaller than in the "Reverse index" case, because in this first option, the multiblock reading operations are realized (Table 6). These operations are more promptly than reading operations in the other options.

TABLE VI. ANALYSIS OF INDEX APPLICATION FOR EFFICIENCY IMPROVEMENT

Different Index Types					
Parameter	*Without Index (Full table scan)*	*Normal Index*	*Reverse Index*	*Bitmap Index*	*Efficiency increase in the best option selection situation*
Cost (%CPU)	405	24	4543	17	16
Physical read	1455	1	125	1280	1455

V. DISCUSSION AND CONCLUSION

Taking into account the contemporary standards and professional studies some conclusions on the relations among QoS and QoE can be formulated. However, firstly, different interpretations of QoE and QoS are developed and widely accepted. The paper aimed to present that categories belong to two different ICT system development environments. QoE focuses on user perception and satisfaction, therefore, QoE metrics should be proposed, specified, evaluated and estimated by end users. Usually, application developers discuss the acceptable metrics and metrics values with end users. The discussions are not a one-time event, but they are repeatable and these metrics ought to be included in the documentation and contract among ICT solution providers and users. On the other hand, the QoS frameworks were originally developed for network management. However, taking into account the ISO/IEC 13236 standard, the term "service" is understood in a very general sense, therefore the wide application of QoS framework is possible [14]. According to that standard, it includes, among others:

- The provision of processing and information repository functions by entities, objects, applications and application processes.
- The interactions between entities, objects, and applications.
- The confidentiality and lifetime characteristics applied to information stored in the information system.
- The communication services.
- The physical equipment.

In the ISO/IEC 13236 standard, a QoS characteristic represents some aspect of a system, service or resource that can be identified and quantified. The QoS parameters are usually, but in unique way, specified in the SLA. These parameters are of different kinds, including:

- A desired level of characteristics, specified by system developers.
- A minimum or maximum level of a characteristic.
- A measured value, used to convey historical information.
- A threshold level.
- A warning or a signal to take corrective actions.

 ISBN: 978-1-61208-416-9

- A request for operations on managed objects relating to QoS.

Taking into account the above mentioned specification of parameter kinds it is difficult to define suitable parameters for database quality improvement. However, the general important QoS characteristics in the ISO/IEC 13236 standard are grouped in the following subclasses:

- Time-related characteristics.
- Coherence characteristics.
- Capacity-related characteristics.
- Integrity-related characteristics.
- Safety-related characteristics.
- Security-related characteristics.
- Reliability-related characteristics.

Within the capacity-related characteristics, capacity, throughput, processing capacity and operation loading are considered. In ISO/IEC 13236, the application information throughput characteristic is defined as an amount of data transferred between applications in a period of time and it is quantified as a rate expressed in bits/second or bytes/second. Beyond that the system throughput characteristic is defined as an amount of processing performed in a period of time. In this paper, authors proposed two metrics, i.e., cost (%CPU) and physical read for database throughput improvement. The measurements are strongly important only for database application developers and not visible to the end users. In the future, authors propose to further develop the system quality measurement from the different ICT system stakeholder point of view.

REFERENCES

[1] Y. Lin, Y. Shi, and S. Ma, "Servitization Strategy: Priorities, Capabilities, and Organizational Features," in Service Science, Management and Engineering, Theory and Applications, G. Xiong, Z. Liu, X. Lu, F. Zhu, and D. Shen, Eds. Amsterdam, Elsevier, pp.11-34, 2012.

[2] P.P. Maglio, S.L. Vargo, N. Caswell, and J. Spohrer, "The service system is the basic abstraction of service science," Information Systems and e-business Management 7, 2009, pp.395-406.

[3] G. R. Gangadhran and E. Field, "Analyzing Requirements and Approaches for Sourcing Software Based Services," Service Science and Logistics Informatics, Luo Zongwei, Ed. Hershey, New York, Information Science Reference, IGI Global, pp. 195-205, 2010.

[4] V. Deora, J. Shao, W. A. Gray, and N. J. Fiddian, "A Quality of Service Management Framework Based on User Expectations," in Service Oriented Computing, M.E. Orlowska, S.Weerawarana, M.P. Papazoglou, and J. Yang, Eds. Berlin, Springer-Verlag, pp. 104–114, 2003.

[5] C. Mendes and M. Mira da Silva, "DEMO-Based Service Level Agreements," in Exploring Services Science. M.Snene, Ed. Belin, Springer, pp.227-242, 2012.

[6] A. Raake and S. Egger, "Quality and Quality of Experience," In Quality of Experience, S.Moller and A.Raake, Eds. Heidelberg, Springer, pp. 11-35, 2014.

[7] Qualinet White Paper on Definitions of Quality of Experience-Output Version of the Dagstuhl Seminar 12181. [Online] Available from: https://tel.archives-ouvertes.fr/IRCCYN-IVC/hal-00977812v1 2015.01.16

[8] M. Varela, L. Skorin-Kapov, and T. Ebrahimi, "Quality of Service Versus Quality of Experience," in Quality of Experience, S.Moller and A.Raake, Eds. Heidelberg, Springer, pp. 85-97, 2014.

[9] B. Weiss, D. Guse, S. Moller, A. Raake, A. Borowiak and U. Reiter, "Temporal Development of Quality of Experience," in Quality of Experience, S. Moller and A.Raake, Eds. Heidelberg, Springer, pp. 133-148, 2014.

[10] M. Garcia, S. Argyropoulos, N. Staelens, M. Naccari, M. Rios-Quintero, and A. Raake, "Video Streaming," in Quality of Experience, S.Moller and A.Raake, Eds. Heidelberg, Springer, pp. 277-298, 2014.

[11] Ch. Timmerer, M. Waltl, B. Rainer, and N. Murray, "Sensory Experience: Quality of Experience Beyond Audio-Visual," in Quality of Experience, S.Moller and A.Raake, Eds. Heidelberg, Springer, pp. 351-366, 2014.

[12] U. Reiter, K. Brunnstrom, K. De Moor, M. Larabi, M. Pereira, A. Pinheiro, J. You, and A. Zgank, "Factors Influencing Quality of Experience," in Quality of Experience, S.Moller and A.Raake, Eds. Heidelberg, Springer, pp. 55-73, 2014.

[13] J. Beyer and S. Moller, "Gaming," in Quality of Experience, S.Moller and A.Raake, Eds. Heidelberg, Springer, pp. 367-382, 2014.

[14] M. Wennesheimer and D. Robinson, "Service Quality Definition and Measurement, A Technical Report," NGMN Alliance, Next Generation Mobile Networks Ltd. Frankfurt, 2013.

[15] Information Technology - Quality of service: Framework, International Standard, ISO/IEC 13236, ISO, IEC, Geneve, 1998.

[16] DSL Forum TR-126. Triple-play Services Quality of Experience (QoE). [Online] Available from: http://www.broadband-forum.org/technical/download/TR-126.pdf 2015.01.15.

[17] A. T. Campbell, "Quality of Service Architecture," Computing Department, Lancaster University, Doctor thesis, 1996. [Online]. Available from: http://www.cs.dartmouth.edu/ ~campbell/papers/thesis.pdf 2015. 01. 15.

[18] User Experience White Paper Bringing clarity to the concept of user experience, Result from Dagstuhl Seminar on Demarcating User Experience, September 15-18, 2010, February 11, 2011. [Online] Available from: http://www.allaboutux.org/files/UX-WhitePaper.pdf 2015.01.16.

[19] Oracle Database Tuning, WebLogic Server Performance and Tuning, 2014. [Online]. Available from: http://docs.oracle.com/ cd/E13222_01/wls/ docs100/perform/ dbtune .html 2014.12.22.

[20] M. Wojciechowski and M. Zakrzewicz, "Cost Optimizer of Queries" Instytut Informatyki, Politechnika Poznanska, 2015. [Online] Available from: http://www.ploug.org.pl/ seminarium/ seminarium_III/ materialy/ kosztowy.pdf, 2015.01.18

[21] B. Bryla and K. Loney, "Database Administration Guide," Helion, Gliwice, 2010.

[22] Database Performance Tuning Guide and Reference, 2002. [Online] Available from: https://docs.oracle.com/cd/ B10501_01/ server.920/ a96533.pdf , 19.01.2015

[23] Database SQL Language Reference, 2015. [Online] Available from: http://docs.oracle.com/cd/B28359_01/ server.111/ b28286/statements_5011.htm#SQLRF01209 , 18.01.2015

[24] Programmer Interview, 2015. [Online] Available from: http://www.programmerinterview.com/index.php/database-sql/cardinality-versus-selectivity/, 10.01.2015