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METHOD OF QUALITY SYSTEMS APPLICATION FOR THE IMPROVEMENT OF MANAGEMENT SKILLS OF MECHANICAL ENGINEERING ENTERPRISES

Field: Mechanical Engineering
Sub-field: Technology of mechanical engineering

Summary of doctoral dissertation

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CONFIRMATION

I confirm that I have developed the Doctoral Dissertation submitted for defense to Riga Technical University for obtaining Scientific Degree of Doctor in Engineering. The Doctoral Dissertation has not been submitted to any other university for obtaining scientific degree.

Guna Civcisa .....

Date: 30 September, 2013

The Doctoral Dissertation is written in Latvian and consists of introduction, 6 chapters, 36 figures, 29 tables, results and conclusions, 172 bibliography sources and contains 182 pages. The total volume of Doctoral Dissertation, including 7 appendixes, is 202 pages.

CONTENT

GENERAL DESCRIPTION OF DISERTATION

Topicality of the research

The Ministry of Economics of the Republic of Latvia (ME RL) in 2006 – 2007 declared that there are several essential problems hindering in Latvia development of small and medium enterprises (SMEs). One of the listed problems is insufficient management skills and knowledge [31] as well as introduction of new business management methods [32].

SME's can with good reason be regarded as a guarantee of economic growth and sustainability of Europe; this is proved by the large number of enterprises in the member states of the European Union (EU). Similarly with situation in EU also in Latvia the biggest part of national economy is constituted by SMEs. Mechanical engineering is among traditional manufacturing branches in Latvia, which is explicitly aimed at export and after the stabilization of economic situation (end of 2009 – beginning of 2010) showed a medium rapid growth and makes significant contribution to the manufacturing industry and all national economy in general [33]. Quality management is crucial for sustainable development of any organization and achievement of planned results. The International Standardization Organization (ISO) already more than 20 years ago developed the ISO 9000 family of Quality Management System (QMS) standards, so that enterprises might apply a quality management approach. During last 25 years different systems and models of quality and general organization's management have been rapidly developed in Europe, America, etc. The ISO 9001 standard for QMS is the most well-known and most applied standard in the world [20]. Application of most quality systems (QS) is not limited as regards the type of economic activity or the size of organization. Until now no data have been available by size classes of enterprises having implemented a certified QMS. Data are available on the total number of certified enterprises. In 2003, 703 enterprises [30] had certified QMS according to the requirements of ISO 9001, but this figure is insufficient to make conclusions about the users of QMS and its spreading in Latvia. The doctoral dissertation shows and analyses data on the proportion of certified QMS in SMEs in Latvia as a whole and also mechanical engineering.

A solution has been developed in the doctoral dissertation how to improve management skills in SME in order to resolve the problems listed by the RL ME. Management of enterprise, like any other process, can be continuously improved; this can be done by the search of new valuable methods aimed at the improvement of performance results. As a result of in-depth analyses of QS and respondent enterprises the most important managerial activities have been established.

The doctoral dissertation is topical because it offers a solution for the improvement of management skills of persons at the highest level (PHL) applying knowledge included in QS. The topicality of doctoral dissertation and research necessity is heightened by the fact that until now in Latvia no researches have been made how actively SMEs apply certified QMS in their business, including also enterprises of mechanical engineering. Nobody has studied the influence of ISO 9001 standard on the enterprises of mechanical engineering on scientific level previously in Latvia.

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Objective and Tasks

The **objective** of the doctoral dissertation is to develop a Method of Quality Systems Application that would promote application of knowledge incorporated in quality systems for management of small and medium mechanical engineering enterprises and enterprises of other branches.

To achieve the objective the following **tasks** have been identified:

1) To develop a method for gathering and analysing statistical data in order to identify the proportion of small and medium enterprises in Latvia and mechanical engineering having implemented a certified quality management system according to the requirements of ISO 9001.
2) To determine the amount of improvements after certification of quality management system in small and medium enterprises of mechanical engineering.
3) To develop a method and succession of its implementation according to which to carry out summarisation and combined analyses of the activities of persons at the highest level defined by quality systems.
4) To develop technique for the assessment of importance and performance of activities carried out by persons at the highest level.
5) To carry out mathematical analysis of the obtained importance and performance evalautions of activities carried out by persons at the highest level.

Object and subject of research

The **object** of the doctoral dissertation is micro, small and medium-sized enterprises, including enterprises of mechanical engineering with certified quality management system according to the requirements of ISO 9001. The **subject** of the research is a method based on the application of quality systems for the improvement of activities of persons at the highest level. The method developed as a result of research can be applied in SMEs of mechanical engineering and any other industries.

Methods of research

In the doctoral dissertation qualitative and quantitative research methods have been used: statistical methods – statistical observation, grouping and sampling method, analysis of absolute and relative statistical quantities, Lickert scale of evaluation, Importance-Performance Analysis (IPA), the ranking of evaluations, graphical method, correlation and regression analysis, survey organization using questionnaires – in paper and electronic form. Close and open type questions and self-assessment method were used in the development of questionnaire. SWOT analysis, QFD (*Quality Function Deployment*) method, scientific literature review, document analysis as well as comparative analysis and synthesis method were also used during research. Data were processed by using softwares as Data Analysis and *QFD Matrix Business Improvement Software*. Data and information are shown in the form of tables and pictures.

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Scientific novelty

1) Questions have been developed for the determination of the amount of improvements in the mechanical engineering enterprises after the certification of quality management system in ten most characteristic fields of activities and the amount of improvements is being assessed. The extent of application of advanced manufacturing technologies has been defined in small and medium enterprises of mechanical engineering in Latvia.
2) New Quality System Application Method has been developed and proposed, demonstrating possible combined application of these quality systems for the improvement of management skills of enterprises of mechanical engineering and other industries. The result of the development of quality system application method – defined 19 activities of persons at the highest level. A mathematical model has been developed for predicting performance of activities of persons at the highest level depending on the evaluation given to importance.

Practical significance

1) The proportion of enterprises by size-classes has been determined for the first time in Latvia in general (the sample size constituted 452 enterprises, statistical data are analysed on 631 enterprises) and separately in mechanical engineering (the analysis was made on all certified enterprises in the industry) which have a certified quality management system according to the requirements of ISO 9001.
2) The amount of improvements was assessed and quantitative indications on the improvement amount in 10 SMEs of mechanical engineering, which have after the quality management system implemented and certified in conformity with ISO 9001 requirements, were obtained.
3) The advanced manufacturing technologies most widely used in the 104 enterprises of Mechanical Engineering and enterprises most active in their application divided by size-classes in Latvia have been established.
4) The importance and performance levels of 19 activities of persons at the highest level have been established and assessed in 13 SMEs in Latvia to determine most valuable managerial activities in the evaluation of these enterprises.

The following research results are defended:

1) Method for determination of the proportion of SMEs in Latvia and mechanical engineering sector having implemented a QMS in accordance with ISO 9001.
2) Research results and data assessment on the improvement amount as well as application of advanced manufacturing technologies in enterprises of mechanical engineering in Latvia.
3) Method of Quality Systems Application for the combined use of quality systems and the identified characteristic activities of persons at the highest level.
4) The research results and data assessment on most significant PHL activities in SME's.

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Research hypothesis

There is lack of management skills at small and medium enterprises in Latvia.

Approbation of dissertation

The results of doctoral dissertation are published in scientific journals, conference proceedings, are reported and discussed at international and local conferences, projects and also study subjects lead by the author.

Publications:

1. Civcisa G. A combined approach for determining managerial activities // Scientific Journal: Management Theory and Studies for Rural Business and Infrastructure Development. - Kaunas: Aleksandras Stulginskis University, Lithuanian Institute of Agrarian Economics, 2012.- No. 2(31), pp. 36-43. ISSN 1822-6760 (EBSCO: Business Source Complete, Ulrich's and Index Copernicus).
2. Čivčiša G. Sertificētu ISO 9001 kvalitātes vadības sistēmu īpatsvars Latvijas mazos un vidējos uzņēmumos // Latgales Tautsaimniecības pētījumi. Sociālo zinātņu žurnāls. - Rēzekne: Rēzeknes Augstskola, Latgales Tautsaimniecības pētījumu institūts, 2010.- Nr.1(2), 56.-67. lpp. ISSN 1691-5828 (Index Copernicus).
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9. Čivčiša G., Grīslis A., Janauska J., Liberts G., Rudņevs J., Salenieks N. Engineering/ Managerial Education for International Business Knowledge in European Small Countries // Agricultural Engineering Problems. Proceedings of the International Scientific Conference. - Jelgava: Latvian University of Agriculture, 2005. - pp. 6-14. ISBN 9984-596-93-1.

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10. Čivčiša G. Kvalitātes vadība – izaicinājums mazajiem uzņēmumiem // RTU zinātniskie raksti. 6. sēr., Mašīnzinātne un transports, 15. sēj. - Rīga: Izdevniecība RTU, 2004. - 32.-38. lpp. ISSN 1407-8015.

Presentations of research results in Latvia:

1. Civcisa G. ISO 9001 Quality management systems in small and medium-sized mechanical engineering enterprises in Latvia // Riga Technical University 53rd International Scientific Conference, Section "Engineering Mechanics and Mechanical Engineering", subsection "Production Engineering", 11-12 October 2012.
2. Čivčiša G. Tehniskās prasības iekārtām un to īstenošanas prakse testēšanas laboratorijā// Riga Technical University 52nd International Scientific Conference, Section „National Economy and Entrepreneurship"; subsection „Quality Technologies and Management", 11 October 2011.
3. Čivčiša G. Piena un piena produktu analizatori mērījumu pareizības nodrošināšanai // Riga Technical University 51st International Scientific Conference, Section "Production Engineering and Transport", subsection „Quality and reliability", 15 October, 2010.
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5. Civcisa G., Janauska J., Mikelsons J., Salenieks N. Inter-countries research for manufacturing advancement (IRMA) in Latvia – the expected benefits // Riga Technical University 50th International Scientific Conference, Section "Production Engineering and Transport", subsection „Quality and reliability", 15 October, 2009.
6. Čivčiša G. Vadīšanas rīcību izzināšana vadības sistēmu skatījumā // Riga Technical University 49th International Scientific Conference, Section "Production Engineering and Transport", subsection „Quality and reliability", 13 October, 2008.
7. Čivčiša G. Mazie uzņēmumi: kvalitātes vadības sistēmu izvērtējums // Ventspils University, 5th. Student Scientific Conference, "Aktualitātes tautsaimniecībā, tulkošanā un tehnoloģijās", Section "Economics and business management", 24 April, 2008.
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11. Čivčiša G. Izcilības prasme amatniecībā Latvijā // Riga Technical University 46th International Scientific Conference, Section "Production Engineering and Transport", subsection „Quality and reliability", 13 October, 2005.
12. Čivčiša G. Kvalitāte amatniecībā // University of Latvia, 63th International Scientific Conference, Section: „Management Science"; subsection: Quality Management", 3. February, 2005.
13. Čivčiša G. Kvalitātes sistēmas dokumentācijas harmonizācija // Riga Technical University 45th International Scientific Conference, Section "Production Engineering and Transport", subsection „Quality and reliability", 14 October, 2004.

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Presentations of research results abroad:

14. Civcisa G. A combined approach for determining managerial activities // International Scientific-Practical Conference „Sustainable development issues for corporate companies and farmers", Aleksandras Stulginskis University, Faculty of Economics and Management, 28-29 June 2012, Kaunas, Lithuania.
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16. Civcisa G. A Comparison of Terms Leadership and Management within Quality Systems // The 12th International Scientific Conference „Economics and Management – 2007", Kaunas University of Technology, Faculty of Economics and Management, 19-20 April 2007, Kaunas, Lithuania.
17. Civcisa G., Salenieks N. Measurement and Uncertainty the way to quality // European Summer University 2006 "Roosts and heritage, factors of European identity: standards and measurement", Pôle Universitaire Normand, 3-7 July, 2006, Havra, France.

The approbation of the results in projects and lectures:

1. 01.01.2008.-31.12.2009. EU Education and Culture DG, Lifelong Learning Programme, „Inter-countries Research for Manufacturing Advancement" (IRMA), IRMA project coordinator in Latvia.
2. August, 2007. RL Ministry of Foreign Affairs, Grant scheme Project "Capacity Building of the Georgian higher education quality improvement", materials for the project „Leadership, Governance and Management Methodologies".
3. May 12, 2007. ESF project for academic staff competence improvement and professional development program "Improving the Quality of Studies" lecturing and material development „Improvement of the Management Methodology".
4. 09/10 AY; 08/09 AY. RTU, FTME, Institute for Quality Engineering (IQE), Masters' study course „ Quality Systems (basics)", (MKI516, 4.0 KP) „ Role of Top Management in Organization".
5. April 25, 2009. RTU, FTME, IQE part time undergraduate study course „Total Quality Management" lecturing and material development.
6. February 2, 2008. University of Latvia, part time undergraduate study course „Total Quality Management" lecturing and material development "Leadership".
7. March 17, October, 13, 2007.g. RTU, FTME, IQE part time undergraduate study course „Total Quality Management" lecturing and material development „Leadership".

Abbreviations

AMT – Advanced Manufacturing Technologies
CSB – Central Statistical Bureau of Latvia
EA code – European Accreditation Code
EC – European Commission
EFQM – European Foundation for Quality Management
EFQM Excellence Model – European Foundation for Quality Management Excellence Model
EU – European Union
EU-27 – European Union Member States after the enlargement on January 1, 2007
ISO – International Organization for Standardization
ISO 9001 – ISO 9001:2008 Quality management systems – Requirements

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LAQ – Latvian Association for Quality
MASOC – Association of Mechanical Engineering and Metalworking Industries of Latvia
MBNQA – Malcolm Baldrige National Quality Award
MBNQA Criteria for Performance Excellence – Baldrige Criteria for Performance Excellence
NACE Rev.2 – Statistical classification of economic activities in the European Community
PHL – persons at the highest level
QMS – Quality Management Systems
QS – Quality Systems
QSA method – Method of Quality Systems Application
RL ME – Ministry of Economics of the Republic of Latvia
SMEs – Small and Medium-Sized Enterprises
Types of PHL activities – management (M), leadership (L), governance (G)

SUMMARY OF DISSERTATION STRUCTURE

The doctoral dissertation consists of the introduction, six chapters, research results and findings. Chapter one assesses the research direction, substantiating the actuality of the chosen topic. Chapter two presents the developed method according to which the results were obtained on the proportion of enterprises in Latvia and in mechanical engineering sector, that have been certified in conformity with ISO 9001. Chapter three comprises an in-depth evaluation of enterprises of mechanical engineering by analysing the extent of application of advanced manufacturing technologies and expected amount of improvements after certification of quality management system ISO 9001. Chapter four presents the development of the method of quality systems application and substantiation of research methods used in its development. Chapter five finalises theoretical development of the method of quality systems application, defines PHL activities and carries out practical researches to test stated hypothesis. Chapter six includes recommendations for the PHL of small and medium enterprises of mechanical engineering and gives recommendations for further researches. The most crucial conclusions are summarised in the research results and findings.

Chapter 1. EVALUATION OF THE RESEARCH AREA

Chapter 1 of doctoral dissertation presents substantiation of the choice of research topic, assessing three directions – quality management, small and medium enterprises and mechanical engineering sector.

According to the EU survey of 2010/2011 SME constitute 99,8% of the total number of EU-27 enterprises, which altogether make more than 20 million [50]. Similarly with the situation in EU also in Latvia the biggest part of national economy is constituted by the proportion of SME, which in 2011 constitutes 99,5% of the total number of enterprises (80 thousand). Classification of SMEs by size-classes was 84,7% micro, 12,3% small and 2,5% medium enterprises [73].

Creation of favourable economic preconditions is one of the most crucial factors affecting and promoting development of SMEs. In the complicated economic situation (which in Europe began in 2008-2009), in order to be able to exist and put the produce on the market, SME need to demonstrate their ability and continuously improve their products. Mastering of a broader market sector is an advantage for any enterprise. Successful alignment with the

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European market can be hindered by insufficient knowledge of the standards. Thus opportunities that enterprises might use when cooperating on an international level are hindered or not used at all.

Considering the importance and input of SMEs into national economy their representatives should be more widely involved and informed about voluntary standards and other QS, as well as about the possibilities to apply them. The family of ISO 9000 standards specifies the requirements and guidelines needed for internal application of organization, so that it would be able to manufacture products satisfying the requirements of customers and legislation [21]. The most widely recognized of ISO 9000 standard family is ISO 9001 containing requirements that should be regarded as additional complementary to requirements for products [22]. The ISO 9001 standard is recognized and applied throughout the world (more than 1 million enterprises) [20]. In Latvia collection of data characterising situation of ISO 9001 certification becomes more complicated with each year. The present situation strongly encumbers performance of research and predicting of trends on the national level. According to the latest publicly available data (January 2010), 703 enterprises have got certificates of conformity with ISO 9001 [30]. ISO organization does not summarize data how many SMEs in the world or Europe have certified QMS; there is no organization summarizing data on the given aspect also in Latvia.

Statistical data (2010) on the extent of ISO 9001 certificates, broken down by industries, on the world scale show that the top five comprise mechanical engineering enterprises, constituting altogether 21% of the total number [20]. According to the results of ISO data analysis one can conclude that in the enterprises of mechanical engineering, certification of QMS according to the requirements of ISO 9001 is widely spread and should be characterised as high.

To assess the tendencies of SMEs the binding industrial policy documents, reports and recommendations of European Commission (EC) have been studied. For the characterisation of economic activity and structure there have been used reports on the Economic Development of RL ME, Central Statistical Board of the Republic of Latvia (CSB), EU Statistical Office (Eurostat), ISO surveys and data of the Association of Mechanical Engineering and Metalworking Industries of Latvia (MASOC).

Evaluation of the quality management direction has been carried out to find out spread of application of QMS in SME, as well as to establish the most widely used standards in SME of mechanical engineering. To characterise spreading of QMS on the world and Latvian scale data of ISO and Latvian Association for Quality (LAQ) on the most widely used standard ISO 9001 have been summarised. Although certification of QMS according to ISO 9001 standard is only one of the quality management approaches yet data on the number of certified enterprises is one of the most widely used evaluation indications.

Evaluation of mechanical engineering sector was started by identifying enterprises belonging to this sector according to the type of their economic activity. The term **"**mechanical engineering**"** is not included in the Regulation No 1893/2006 of the European Parliament and of the Council [13], establishing the statistical classification of economic activities NACE in the European Union (NACE Rev.2), therefore an analysis of the classification of mechanical engineering was carried out. Interpretations of European and national level organizations are compared regarding classification of mechanical engineering. Based on the results of comparison mechanical engineering is defined and according to it the

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research data gathering and result collection is made. Data of CSB and MASOC are analysed to determine the total number of enterprises of mechanical engineering and their distribution by size-classes in Latvia.

Chapter 2. PROPORTION OF QUALITY MANAGEMENT SYSTEMS IN SMALL AND MEDIUM ENTERPRISES AND MECHANICAL ENGINEERING IN LATVIA

Chapter 2 of the doctoral dissertation includes solution of the first task of the thesis. It was impossible to collect data necessary for the solution of the first task by using any data base where according to the search criteria interested information can be selected. To solve the first task and identify the proportion of SMEs in Latvia and in mechanical engineering a method was developed for statistical data collection and analysis. Data necessary for the analysis were obtained using the publicly available data bases of LAQ, "The Compass Group", "Lursoft" and MASOC. The gained results allow making conclusions about the spread of certified QMS broken down by enterprise size-classes in Latvia in general and in mechanical engineering.

2.1. Proportion of certified ISO 9001 in small and medium-sized enterprises in Latvia

For the first time results were gained about the proportion of certified enterprises in Latvia and in mechanical engineering where conformity to the requirements of ISO 9001 have been evaluated. The made research is the first systematized data collection which cannot be gained in annual ISO surveys and publicly available data bases of other organizations (for example, certification bodies in Latvia, LAQ, MASOC).

Method for determination of the proportion of certified QMS envisages two steps: 1) to collect adequate data on each object under investigation taking into consideration two essential features (existence of ISO 9001 certificate and size of organization according to the number of employees), 2) to systematise the collected data and carry out statistical analysis. Data for research purposes were obtained from the LAQ [29] data base of certified enterprises by, containing collected and publicly available register of all enterprises certified by LAQ irrespective of the certification body that has issued ISO 9001 certificate. Identification of the number of employees engaged in the enterprise was the most labour consuming process in the path of this study task. The necessary information was obtained in publicly available data base of B2B "Compass Group", which was chosen as the most suitable in view of the research needs and resources. Belonging of enterprise to each group of definite size was determined according the Recommendation of European Commission (EC) 2003/361/EC [14]. Taking into consideration that financial data of organizations is confidential information, enterprises were grouped according to the number of employees. The chosen approach is taken over from the "Eurostat" business structural statistical data classification. During research data on 631 enterprises (2008) [29], which have received ISO 9001:2000 certificates were analysed. This can be explained by the fact that the research was started before the new version (2008) of the standard took effect and the standard transition period stage (November 15, 2008). It is impossible to carry out research on enterprises which have received ISO 9001:2008 certificates of conformity, because, as was noted in Chapter 1, a later register of certified enterprises is not available for public at present.

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Having obtained the necessary data the second step of the method was carried out and the obtained data were systematised and analysed statistically. In the path of analysis each enterprise was observed and for data systematisation electronic data base was created which ensured convenient making of analyses and preparation of clear results. When determining the proportion of enterprises by size-classes, which have certified QMS, data were processed and analysed regarding four enterprise size-classes.

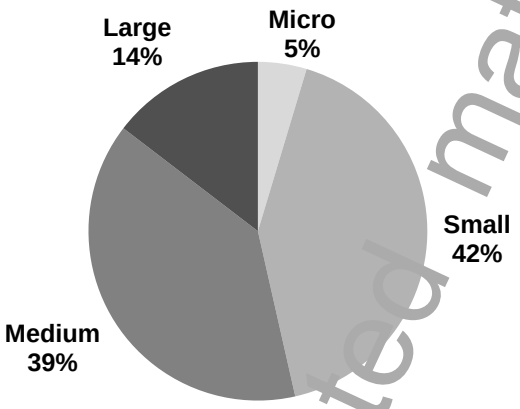

Figure 2.1. Proportion of ISO 9001:2000 certificates by enterprise size-class in Latvia

Source: research of author

According to the simple size (452 enterprises), it was concluded that the relative frequency of proportion of certified enterprises is within the interval ± 2.46%in the population with a confidence level of 95%.

According to the developed method for the determination of SMEs proportion the results were gained about the general situation in Latvia. After evaluating the collected research results one can conclude that most (Figure 2.1) ISO 9001 (2000) certificates were issued for small– 42% and medium-sized enterprises, constituting together 81% of total. Among these two groups the distribution is almost similar - in the group of small – 189 and medium – 176 enterprises. The class of SMEs together constitutes 86%, but micro enterprises make only 5% from the total number, therefore they should be regarded as the least active size-class of enterprises. The third largest group regarding QMS certification is large enterprises – respectively 14%.

The distribution results of certified enterprises allow characterising and making conclusions about enterprises by size-classes in Latvia. The obtained results are useful when comparing the growth or reduction tendencies by years on national, regional and international scale.

2.2. Proportion of certified ISO 9001 small and medium-sized mechanical engineering enterprises in Latvia

An extra analysis was carried out when determining the proportion of certified enterprises by size-classes in Latvia, in order to determine the spread of QMS in the mechanical engineering sector (Table 2.1). The amount of certified QMS spread by sectors was determined according to European Accreditation Code (EA code) classification being used by ISO, as well as accreditation and certification institutions. EA codes are inter-

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comparable with NACE Rev.2 codes, therefore they ensure convenient transition from one classification codes to another [19].

Table 2.1

The number of ISO 9001 certificates in Latvia by industrial sector

No	Description of industrial sector according EA codes	Relative frequency, %
1	EA 28 Construction	18
2	EA 35 Other services	12
3	EA 29 Wholesale and retail trade; Repair of motor vehicles, motorcycles and personal and household goods	10
4	EA 31 Transport, storage and communication	9
5	EA 34 Engineering services	8
6	EA 17 Basic metals and fabricated metal products	5
7	EA 19 Electrical and optical equipment	5
8	EA 36 Public administration	5
9	Other sectors	28

Source: author's calculation and design based on LKA data [30], 2010

Information on the extent of ISO 9001 certificates by sectors characterises general situation in Latvia as well as allows to find out the enterprises of which sectors choose most often to obtain the ISO 9001 certificate of conformity for its QMS. Table 2.1 includes sectors where the amount of enterprises having received a certificate of conformity to ISO 9001 reaches at least 5% of the total amount. Analysing the situation of mechanical engineering sector in Latvia it was stated that 5% of basic metal and fabricated metal product manufacturing sector (EA 17) enterprises have certified QMS according to the requirements of ISO 9001. The machinery and equipment manufacturing sector (EA18) is not included in Table 2.1 because the amount of certified enterprises constitute only 1% of the total number of certified enterprises in Latvia. According to the borders of mechanical engineering defined in the Doctoral Dissertation (EA 17 and EA 18) one can regard that in Latvia from the total number of enterprises (703 in 2010), which have a certified QMS according to the requirements of ISO 9001, about 6% are constituted by enterprises of mechanical engineering (total number – 46). For comparison, in the world altogether 21% of enterprises of mechanical engineering sector have certified QMS according to ISO 9001 requirements [20].

To determine the proportion of certified enterprises by size-classes in mechanical engineering an identical method was used as to state general situation in Latvia. Data for situation analysis were gained in MASOC data base [4] where extended information on enterprises of mechanical engineering is available. Information on each observed enterprise is included in the data base, which is made in MS Excel to systematise the selected data according to the following parameters: title, number of employees, NACE Rev.2 code, certificates, used manufacturing technologies, etc. As a result of data selection and processing (taking into consideration limits defined by mechanical engineering sector) it was stated that in 2011, 104 enterprises of mechanical engineering had registered at MASOC. 46% or 48 enterprises of MASOC, the business activities of which fall within the limits of the sector under research, have the ISO 9001 certificate of conformity [38]. It was stated that altogether there were 46 enterprises of mechanical engineering in Latvia (2010), which have an ISO 9001 certificate; thus it can be stated that the whole population size was estimated within the

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research. Since the results of analyses cannot be completely transferred to the population, 95% confidence level is assumed. A slight shifting in the number of enterprises can be explained by the fact that it is impossible to get statistical data only regarding one year.

The results gained by the analysis show that 92% of sample enterprises belonging to mechanical engineering are SMEs, and the biggest part – 59% is constituted by medium enterprises. The smallest part is constituted by micro and large – 4% and 8% respectively. Comparing the proportion by size-classes in Latvia in general with situation in mechanical engineering, one can conclude that SMEs of mechanical engineering have proportionally more (by 6 percentage points) introduced certified QMS. If in Latvia in general the proportion between the classes of small and medium enterprises is nearly similar (respectively 42% and 39%), then in the enterprises of mechanical engineering the number of certified medium enterprises is twice bigger than in the class of small enterprises (respectively 59% and 29%).

Chapter 3. EVALUATION OF IMPROVEMENTS IN SMALL AND MEDIUM ENTERPRISES OF MECHANICAL ENGINEERING

Chapter 3 of the doctoral dissertation covers solution of the second task. The chapter comprises in-depth assessment of enterprises of mechanical engineering to determine the amount of expected improvements after the certification of quality management system according to the requirements of ISO 9001 standard. The Chapter analyses the extent of application of advanced manufacturing technologies in SMEs of mechanical engineering. Enterprises of mechanical engineering are assessed in view of certified and uncertified quality management system factor and its effect on the application of advanced manufacturing technologies is determined. A method has been developed and substantiated for the assessment of the amount of improvements in SME of mechanical engineering having certified quality management system according to the requirements of ISO 9001. The principles of respondent selection and survey organization are outlined. The results of empirical research on the amount of improvements in SMEs of mechanical engineering in Latvia after certification of quality management system are assessed.

3.1. Assessment of application of Advanced Manufacturing Technologies

Literature lists up to 45 different types of advanced manufacturing technologies (AMT). When analysing the application of AMT, a sample was used as well as data base which has been made to determine the proportion of certified quality management systems in enterprises of mechanical engineering (Chapter 2). To determine the extent of AMT use in SMEs of mechanical engineering in Latvia, data available in the MASOC data base [4] were used, which were summarised and processed according to the needs of the research. From the range of technologies, being used by Latvian enterprises that are listed in the MASOC data base, data on six types of technologies which according to the review of literature are regarded as AMT, are being used for further analysis. Absolute and relative frequency of application of all six AMT types is given in Table 3.1. For data systematization and processing a database was created where the established sample data set were processed. The analysis covered 104 enterprises where 119 cases of AMT use were stated. According to the observed simple size by studying 104 enterprises it can be argued that the result confidence interval in the population is ± 9.34%, with 95% confidence level.

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The analysis of the application of AMT shows that from these six AMT types in the enterprises of mechanical engineering most often they use computer numerical control (CNC), i.e. 60%. The second most often used type of AMT is computer aided design (CAD); frequency of use constitutes 14%. Other four types (EDM I*, EDM II*, robot welding, CMM) are being used on the average 9 times less than CNC.

When analysing data by enterprises' size-classes it was established that most of all AMT are being used in small (53%) and medium (38%) enterprises of mechanical engineering.

Table 3.1

Frequency of application of Advanced Manufacturing Technologies in Mechanical Engineering enterprises

Advanced Manufacturing Technologies	Frequency	Relative frequency (%)
1) computer-aided design (CAD)	17	14
2) computer numerical control (CNC)	71	60
3) electrical discharge machining (EDM I*)	9	8
4) wire-cut (EDM II*)	8	7
5) robot welding	6	5
6) 3D coordinate measuring (CMM)	8	7

* Since two technologies have similar abbreviations, EDM was given symbol I or II.

Source: author's calculation and design based on MASOC data, 2012

When comparing the obtained data with the number of enterprises, they do not differ essentially in groups of small and medium enterprises (the proportion is similar). The situation is inversely proportional in the groups of micro and large enterprises; if the number of micro enterprises is numerically larger than the number of large enterprises in general, then AMT they use least (in amount of 3%) of all four enterprise size-classes.

To find out whether enterprises having implemented a certified QMS according to the ISO 9001 use AMT more, a comparative analysis was carried out by enterprise size classes in mechanical engineering sector. The analysis covered two most often used technologies – CAD and CNC. Enterprises of mechanical engineering, considering their size-classes, are grouped according to two factors: 'ISO 9001' – enterprise has a certified quality management system and 'No'– enterprise has no certified quality management system.

The results of analysis on the extent of use of CAD and CNC technologies in all enterprise groups in general and separately by enterprise size-classes differ. In the group of large enterprises (Figure 3.1) all enterprises have a certificate of conformity to the requirements of ISO 9001, of which CAD is being used by 25% and CNC – 75% of enterprises. In the group of medium enterprises CAD is being used by 24% and CNC – by 79% of enterprises with ISO 9001 certificate of conformity, but in enterprises that do not have ISO 9001 certification CAD technology is being used by 16% and CNC – 74%. In the group of small enterprises CAD technologies are being used proportionally equal between enterprises that have and do not have ISO 9001 certificate – 14% respectively. CNC is being used by 79% of small enterprises having ISO 9001 and 59% – without ISO 9001 certificate of conformity. It was established that in the group of micro enterprises CAD technologies are not

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used; regarding use of CNC comparative results cannot be given (78% of micro enterprises do not have ISO 9001 certificate).

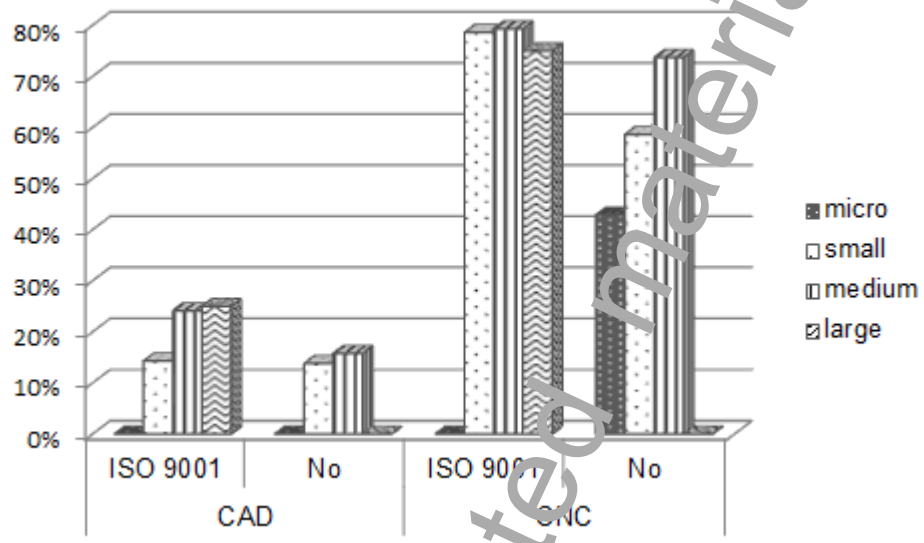

Figure 3.1. Frequency of AMT application within context of ISO 9001

Source: research of author, 2013

As a result of comparative analysis of use of both technologies one can observe a tendency that CAD and CNC technologies in general are more used by enterprises having implemented a certified QMS according to the requirements of ISO 9001. Four and five AMT types simultaneously are used only by two enterprises; besides both fall under the group of SMEs and both have ISO 9001 certification.

3.2. Assessment of the extent of improvements after introduction of ISO 9001

The assessment of improvements after certification of QMS was carried out to find out what in the internal operation of SMEs of mechanical engineering has improved most and what advantages enterprises can gain from having ISO 9001 certification. The ten questions were drawn up to determine the extent of improvements; to develop these questions researches on the assessment of enterprises' efficiency and the impact of ISO 9000 standards on enterprises were analysed [36], [40], [42], [43], [3], [8], [2].

To determine the amount of improvements in SMEs of mechanical engineering in Latvia a qualitative data collection method – interviewing was chosen as a pilot version. After consultations with leading Latvian quality management professionals and one interview carried out in an enterprise of mechanical engineering the research method was substituted by the quantitative method – questionnaire. The primary task of survey was to obtain parameters of the extent of quantitative improvements. The range of respondents covered by survey was identified using information included in MASOC data base and enterprise home pages. The sample of the survey was selected taking into consideration specific needs of the research and it was formed from enterprises, which:

a) fall under the group of SMEs;
b) are enterprises of mechanical engineering (NACE Rev.2), within the limits defined in the doctoral dissertation;
c) have a certified QMS according to the requirements of ISO 9001.

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To determine the extent of improvements ten assessment questions were developed which were specifically adapted to the enterprises of mechanical engineering. Percentage interval scale was used for the assessment of the amount of improvements (improvement magnitudes were measured by intervals). One evaluation scale was used for the assessment of all 10 questions. In each question the extent of improvements could be evaluated on the scale from 0% (no improvements) up to 36% and more (essential improvements). The evaluation scale uses six step gradation scale of which five were on the interval scale (1 – 5%, 6 – 15%, 16 – 25%, 26 – 35% and 36% and more), but in cases where no improvements were stated, 0% evaluation was used.

Enterprises' responsiveness to participate in the survey should be evaluated as good, taking into consideration that data on the amount of improvements had to be submitted in quantitative expressions. At the end of survey 10 valid responses were obtained from SMEs of mechanical engineering sector. All survey participants were guaranteed confidentiality of the provided data; therefore the obtained results are not expressed in connection with the title of a definite enterprise, but are being used in the analysis of the amount of improvement in general. Each survey participant could choose whether the enterprise title is to be mentioned in the research survey or not. Five of enterprises involved in the survey agreed to make the enterprise title available to public – *Auto Cardan* Ltd., *Jelgavas mašīnbūves rūpnīca* JSC, *LEAX Rēzekne RSEZ* Ltd., *Tehnika Auce* Ltd., and *Z metals* Ltd.

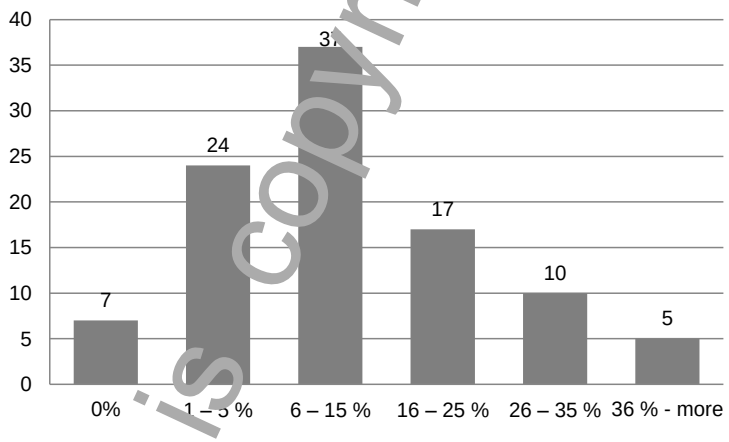

Figure 3.2. The average amount of improvements

According to the results provided by the SMEs of mechanical engineering most often 6 –15% amount of improvements is to be expected after the QMS certification. Generally all surveyed enterprises, giving answers to 10 questions, 37 times have indicated 6 – 15% amount of improvements, which is about 1,5 times more often indicated as the second (1 – 5%), and about 2 times more often indicated (16 – 25%) as the third amount of improvements. In the process of data analysis for the evaluation of improvement extent, descriptive and inferential statistics were used, as well as MS Excel and its tool Data Analysis. The overall assessment of the amount of improvements forms a normal distribution (Figure 3.2).

According to this research predictions can be made that after QMS certification in accordance with the ISO 9001the enterprise most probably will gain improvements in the amount of 6 – 15 %, yet a possibility should not be excluded that the reached benefit would adjoin to 0% or exceed 36%, which is included in the research as the lowest and highest evaluation of the amount of improvements.

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After general evaluation of improvements each survey question was analysed. To analyse the received evaluations more precisely, then for each evaluation of improvement amount was given different weight: 0 (rating 0%), 1 (rating 1 – 5%), 2 (rating 6 – 15%), 3 (rating 16 – 25%), 4 (rating 26 – 35%) and 5 (rating 36% and more) and the average value,, standard deviation and weighted average of improvement amount were calculated (Figure 3.3).

The results of empirical research are arranged in the succession downwards, starting with the indications of the largest weighted average improvement amount. The weighted average was chosen as a primary of the calculated statistical indications, because not only ratings are taken into consideration, but also the number of repetitions of each rating. According to the received results one can state that the biggest improvements after introduction of ISO 9001 are connected with a possibility to master new foreign markets (Q10). When giving answer to the 10th question representatives of 50% enterprises have indicated that the amount of improvements is 16% and more per cents, and 40% have pointed to 26% and more per cent improvements.

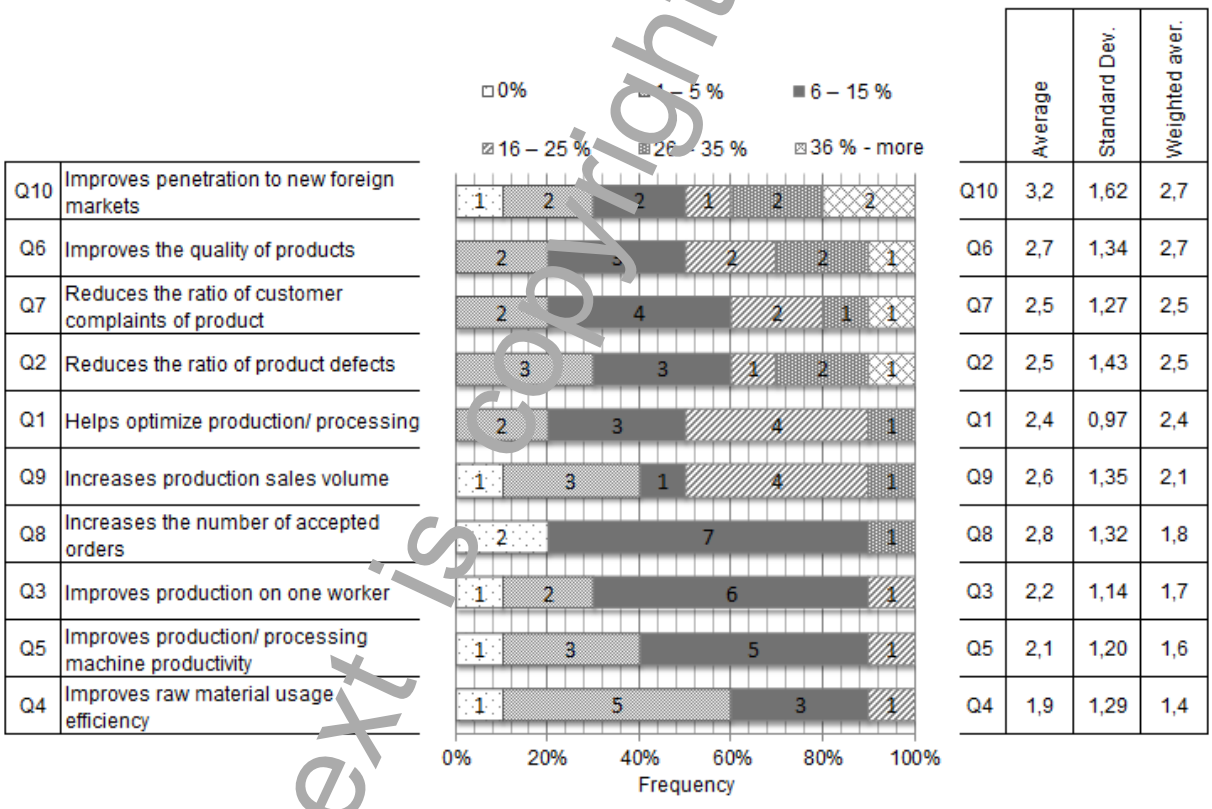

Figure 3.3. Results of the empiric research on the amount of improvements

Second highest evaluated improvement is the improvement of the quality of manufactured/processed products (Q6). Giving answer to the 6th question again 50% of enterprise representatives have pointed out that improvements constitute 16% and more, but 26% and more improvements were mentioned by 30% enterprises. Comparatively high improvements were pointed out also in the second (Q2) and seventh (Q7) questions. In both questions 16% and more improvements were pointed out by 40%, but within the range from 1 – 15%, respectively were indicated by 60% enterprises. The third place in the rating of amount of improvements is given to Q7 – reduced ratio of customers' complaints about the

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product, but the fourth place to Q2 – reduced ratio of product defects. Although both of these questions have the same weighted average and also average values, yet values of standard deviation are different.

The fifth and the six places in the ranging are taken by Q1 and Q9. When giving answers to the first question 50% enterprise representatives have pointed out that the amount of improvements constitute 16% and more, but the remaining 50% have indicated 1 to 15 % improvements. Answering to the ninth question 50% enterprise representatives have pointed out that the amount of improvements constitutes 16% and more, 40% have indicated improvements from 1 to 15%. According to the weighted average (from 1,8 to 1,6) questions Q8, Q3 and Q5 are placed in the 7-9 places (Figure 3.3). The lowest improvement amount evaluation is given to the fourth question. Half of the surveyed enterprises have pointed out that the amount of improvements is within the range of 1 – 5 %.

After summarization of the results given by SMEs of mechanical engineering one can conclude, that in no one of the survey questions the given improvement amount would be 0% (no improvements at all). Therefore according to the research results, it can be regarded that improvements after the implementation of the ISO 9001 are to be expected regarding all questions. Having evaluated the results of empirical research one can be expected that for enterprises of mechanical engineering after QMS certification according to the requirements of ISO 9001 standard export possibilities will grow, also product quality will be improved, as a result customers' satisfaction with the final product will be raised and the ratio of product defects will be reduced.

Chapter 4. DESIGN AND DEVELOPMENT OF METHOD OF QUALITY SYSTEMS APPLICATION

Chapter 4 of the doctoral dissertation studies the third work task, describing consistently the sequence of development of Method of Quality Systems Application (hereinafter – QSA method) envisaged for the use of knowledge incorporated in QS in the management of small and medium enterprises of mechanical engineering and enterprises of other sectors. The developed QSA method consists of 4 steps, 3 of which are set out in this Chapter – selection,, analysis and synthesis of three quality systems.

4.1. Theoretical background for analysis of persons at the highest level

The development of QSA method was started with the summarisation of the conclusion of scientists and researchers about the importance and effect of PHL on enterprise management. Importance of PHL and their activities are widely discussed in literature. Several different terms are being used in QS that are to be attributed to enterprise management. Theoreticians and practitioners are being analysed within framework of the thesis that have focused on the explanation of importance of manager's functions and activities.

The first and in the world best known developers of the quality philosophy, such as W. Edwards Deming [11], Joseph M. Juran [25] and Philip B. Crosby [10] have stressed the importance of PHL, which is at the basis of any successful operation of an organization. The importance of managers/leaders is emphasized also by contemporary theoreticians and practitioners – John S. Oakland [39] has made contribution to leadership issues, D. L.

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Goetsch, and S. Davis, believe that leadership is an intangible concept giving tangible results (23), B. Bergman, and B. Klefsjo stress the role of management, especially top management and involvement into quality improvement [5], as well as other authors J. Adair, [1], N. Jabnoun and H.A. Al-Ghasyah [23], G.K. Kanji, [26] have made studies on leader's activities and qualities. The importance of persons at the highest level is emphasized also by Latvian scientists and practitioners – I. Forands [15], [16], as well as J. Leiladis and Dz. Putnis [6].

Sources of scientific literature discuss broadly a standpoint on leadership and management, besides there are different points of view among authors: P. Taffinder [48], D. L. Goetsch, and S. Davis, [17], as well as R. D. Snee and R.W. Hoerl [46], B. Bergman and B. Klefsjo [5], I. Forands [15], M. Božič [7], J. Kotter [27], as well as F. A. Meyer [35], P. Sydänmaanlakka [47], J. Adair [1]. A literature review and views on leadership and management have been conducted.

In the doctoral dissertation a neutral attribute – person at the highest level – is being used instead of the term top management in order not to stress any of the discussed theories, as well as to use a possibly general attribute and as a result to identify a broader set of activities implemented by PHL.

4.2. Development of QSA method: step 1 – selection of three quality systems

The 1st step of the QSA method development – selection of the quality system was started with the selection of criteria needed for assessing the suitability of QS. Since the development of QSA method is aimed at the persons at the highest level, then QS was chosen according to such criteria, so that 1) it would be possible to study activities of PHL and 2) they would be suited for the special target group of the research. The author of the work has developed seven criteria needed for the assessment of QS suitability.

The following criteria were worked out for QS selection:

1) Appropriate for for small and medium-sized enterprises;
2) No restriction on the economic sector;
3) Managerial principles are included;
4) Activities to be performed by the persons at the highest level of organization are defined;
5) Internationally recognized and distinguished;
6) Periodically reviewed and updated;
7) Known and/or used by enterprises in Latvia.

After the assessment of QS it was decided to use in the development of QSA method three QS recognized globally.

This Chapter describes all four implementation tasks of Step 1 (Table 5.2.), as well as gives general description and substantiation of selection of ISO 9001:2008 Quality management systems – Requirements (hereinafter ISO 9001), European Foundation for Quality Management Excellence Model (hereinafter EFQM Excellence Model) and Malcolm Baldrige National Quality Award Criteria for Performance Excellence (hereinafter MBNQA Criteria for Performance Excellence).

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4.3. Development of QSA method: step 2 – analysis of three quality systems

Step 2 of the development of QSA method covers analysis of three selected QS: ISO 9001 [22], EFQM Excellence Model [12] and MBNQA Criteria for Performance Excellence [37]. The analysis was carried out to identify what terms for PHL designation are being used in each QS, as well as a possibility to compare them mutually. Terms being used for the designation of PHL activities are also been assessed. In order to identify terms used for the designation of PHL and their activities the respective chapters and criteria of selected QS were studied. Mutual comparison of terms allows to understand which terms are dominating in each QS, and definitions help to understand to the meaning of PHL activities. After an in-depth analysis of terms it was stated that in each quality system different terms are being used for the designation of PHL and their activities, and explanation of definitions also differ. The diversity of terms used within the three QS are not a ground to declare that QS differ from each other also as regards the content, therefore in the 2nd step of QSA method QS principles were also analysed. Initially principles of each QS were studied separately, afterwards the content similarities were analysed mutually, paying particular attention to principles emphasizing participation of persons at the highest level. As a result of mutual comparison of QS it was established that QS have different structure and application. Although usage of EFQM Excellence Model and MBNQA Criteria for Performance Excellence is similar – making self-assessment for the preparation of application for quality award, yet the structure of both QS is different. The structure and usage of ISO 9001 cannot be compared with both quality award models. Regarding the content, QS are similar because of the fact that activities to be performed by PHL are defined and in each of them one principle is about the importance of PHL in the organization.

Since the development of QSA method is aimed at the improvement of PHL activities the suitability of QS application was verified to find out whether QS can be used as an instrument improving the PHL performance and allowing to achieve the objective of the Thesis. The Author has gained confirmation that the three selected QS (ISO 9001, EFQM Excellence Model and MBNQA Criteria for Performance Excellence) can contribute to the improvement of PHL activities, therefore the next step of Method for AQS can be implemented.

4.4. Development of QSA method: step 3 – synthesis of activities of persons at the highest level

In the 3rd step of the development of QSA method – synthesis of activities of persons at the highest level, an in-depth comparative study of PHL activities is carried out to establish uniting and different managerial activities in the context of QS. Mutual comparison of QS was done evaluating the degree of similarity of PHL activities. The mutual comparison of selected QS was carried out as follows:

1) Subchapters (5.1.-5.6.3.) of Chapter 5 of ISO 9001 standard are compared with paragraphs (1a.(1) – 1e.(9)) of Criteria 1 of EFQM Excellence Model;
2) Subchapters (5.1.-5.6.3.) of Chapter 5 of ISO 9001 standard are compared with paragraphs (1.1a[1] – 1.2c) of Criteria 1 of MBNQA Criteria for Performance Excellence;

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3) Paragraphs (1a.(1) – 1e.(9)) of Criteria 1 of EFQM Excellence Model are compared with paragraphs (1.1a[1] – 1.2c) of Criteria 1 of MBNQA Criteria for Performance Excellence.

Three tables (matrices) were developed for making comparison including the degrees of similarities of PHL activities. Assessment of linkages having three different levels, allowing to determine simultaneously the closeness of linkages between PHL activities and gain quantitative values. Three rating levels are used in the comparison of linkages between PHL activities: "5" (very close link), "3 "(medium close link) and "1" (weak link).

Carrying out mutual comparison of QS to determine the degree of similarity of PHL activities between corresponding subchapters/subcriteria of ISO 9001, EFQM Excellence Model and MBNQA Criteria for Performance Excellence it was established that there are very close, medium close and weak links among three systems, and also that there are no links between definite PHL activities. Assessment of all three QS was carried out in the course of comparative analysis. Simultaneously a comparative analysis of two systems was carried out allowing to determine in which sections of "one" system one can identify similarities with some of sections of the "other" system, and vice versa, in which sections of the "other" system similarities can be observed with the sections of the "first" system.

Based on the results of analysis of PHL terms (step 2) and results of comparative analyses and synthesis of PHL activities at the end of step 3 of QSA method there are defined three types of activities by PHL – management, leadership and governance (hereinafter M-L-G). To substantiate the three defined types of PHL activities, research papers have been summarised where authors separate three management types. N. Salenieks, [24], [9], as well as Luc E. Weber [49] and M. Pupius [41] points out to the leadership, governance and management.

Chapter 5. CHARACTERISTIC ACTIVITIES OF PERSONS AT THE HIGHEST LEVEL AND THEIR EVALUATION

Chapter 5 of the doctoral dissertation includes solutions of tasks four and five of the thesis, studies theoretical aspects of PHL activities and makes practical researches on SMEs management skill improvement. Chapter covers the final step of the development of QSA method and the developed activities for its practical application. The validity of PHL activities developed by the author is tested and confirmed. Practical part of the Chapter consists of the experimental testing of the results of theoretically developed QSA method, analysis of the obtained data and processing of results with statistical methods. The most important PHL activities and their implementation level in practice have been stated from the point of view of SMEs. Possible scenarios have been drawn up and the research method selected for the development of recommendations.

5.1. Development of QSA method: step 4 – interpretation of PHL activities

In the final step 4 of the development of QSA method – interpretation of PHL activities - interpretation of characteristic activities of PHL is carried out based on the terms used in three QS for designation of PHL activities, the proportional amount of types of PHL activities, as well as types of PHL activities identified in literature.

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Table 5.1

Key activities for the persons at the highest level

Symbol	Management activities	Symbol	Leadership activities	Symbol	Governance activities
M1	Creation of the quality policy	L1	Involvement and encouragement of people	G1	Responsibilities to the society
M2	Selection of methods for customer satisfaction measurements	L2	Provision of sustainability to an organization	G2	Attraction of independent advisory body
M3	Definition of responsibilities for people	L3	Communication on development directions of an organization	G3	Performance evaluation of the chief executive and member board
M4	Review of objectives and assessment of performance	L4	Capability for rapidly changes, analysis of internal and external environment	G4	Establishment of system for strategy implementation
M5	Balance of resources to ensure the effectiveness of an organization	L5	Promotion of people potential and growth	G5	Anticipation and dealing with concerns of society
M6	Appointment of management representative to establish the quality management system	L6	Establishment of organizational structure and related mechanisms	G6	Development of ethic and behaviors model
M7	Observation of the statutory and regulatory requirements				

PHL activities are classified into three groups (M-L-G) according to their features (typical characteristics), which were stated comparing PHL activities among three QS. Figure 5.1 shows that a combined comparing has allowed to analyse simultaneously all three QS and to determine three types of PHL activities – management, leadership and governance, which would not be possible if the developed QSA method would be used analysing only one quality system. As a result of development of QSA method three types of PHL activities were defined – management, leadership and governance, as well as 19 key (Table 5.1.) and detailed descriptions (were included in the survey) of PHL activities were developed.

5.2. Summary of the development of Method of Quality Systems Application

The QSA method developed by the author in general consists of four steps (Figure 5.1). All steps are interrelated and each following step is being developed based on the results of previous step, therefore they are to be used in succession. For the implementation of each step of QSA method it is necessary to perform several (three or four) tasks listed in Table 5.2.

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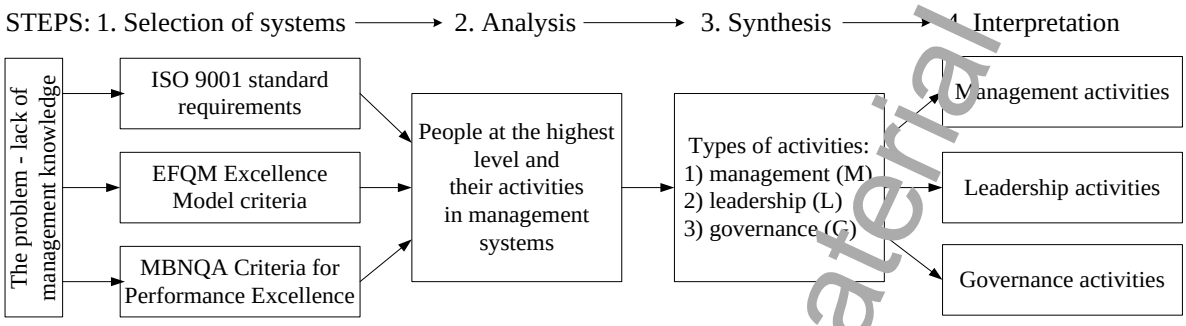

Figure 5.1. Method of Quality Systems Application

The QSA method can be implemented taking into consideration the sequence of all steps and tasks. In the development of QSA method the scientific research methods of quality management field were used.

Table 5.2

Tasks for the implementation of Method of Quality Systems Application

Step 1	Selection of systems	To develop criteria for evaluating the appropriateness of management systems within the identified needs/scope
		To identify the existing management systems in accordance with the required needs/scope
		To assess the selected management systems according to criteria
		To select the most appropriate management systems
Step 2	Analysis	To determine used terms and their interpretations in management systems to designate person at the highest level
		To evaluate the guidance in the management systems for activities taken by the person at the highest level
		To compare the principles of management systems and to identify their interrelationships and similarities
		To identify links between the principles and the sections and the criterion of management systems
Step 3	Synthesis	To determine the corresponding sections and criterion in the management systems to compare activities for person at the highest level
		To carry out a comparison between activities implemented by person at the highest level
		To define the types of activities for person at the highest level (M-L-G)
Step 4	Interpretation	To develop key activities for person at the highest level and to classify them by types of activities
		To review and to adjust key activities of person at the highest level by considering specific needs/scope
		To develop detailed descriptions of activities (criteria) for assessment by measuring importance and performance

The QSA method is a new solution allowing to combine guidelines/requirements to the enterprises' PHL given in three different QS, thus identifying a possibly wider range of

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management skills. The author has not found any information in literature that previously an equivalent study by combined use of three quality systems has been performed.

5.3. Approbation of results of theoretically developed QSA method

According to the developed QSA method, 19 key activities of PHL were established and these activities were analysed in practice to test the research hypothesis and state whether there is any difference between the actual and expected managerial performance level. To find out the opinion of SMEs representatives, technique were developed which helped to assess the importance and performance levels of PHL activities. The objective of the development of technique was 1) to get evaluation from PHL, whose enterprises have a certified QMS according to the requirements of ISO 9001; 2) to gather and analyse key activities of PHL being put into practice in SMEs in Latvia. The developed technique for the assessment of PHL activities envisages combined use of three research methods (survey, Lickert scale of evaluation and IPA analysis). To get the assessment from the SMEs representatives (managers/owners/quality managers) a specially designed questionnaire was used. The questionnaire is structured in three parts. The first part of the questionnaire comprises general questions, and the second part includes the developed technique for the assessment of PHL activities. The third part is as open-type questions so that respondents might express their opinion.

The second part of the questionnaire includes 19 identified PHL activities, which for the purpose of learning opinion were developed in the form of detailed questions. The technique for the evaluation of PHL activities envisages that respondent giving answers to all 19 questions carries out self-assessment. Respondents simultaneously assessed the level of importance and the level of performance of each question (PHL activities), using the evaluation scale from 1 to 5. Higher evaluation score means that PHL activity is more important ("5" "vitally important" to "1" "completely unnecessary") and performance higher ("5" "excellent" to "1" "do not implement").

At the end of survey there were gained data from 13 manufacturing, including mechanical engineering (23% of the total sample) and service sector SMEs, which have a certified QMS. The average age of enterprises involved in the survey is 11,3 years; it means that experienced and stable enterprises participated in the survey. The experience of enterprises to work according to the requirements of ISO 9001 is proved by the fact that 9 of 13 enterprises have had at least one or several recertification audits. For all 13 enterprises the market of manufactured products / provided services is Latvia, but 31% has market also outside Latvia.

A technique worked out by the author allowed to learn and assess the opinion of SME representatives on the importance and performance levels of 19 PHL activities, as well as gain results for testing the research hypothesis.

5.4. Processing and analysis of research results

The results of empirical research on the levels of importance and performance of PHL activities were processed using IPA analysis and making a two-dimensional grid (envisaged by the technique for the evaluation of PHL activities developed by the author). The IPA two-dimensional grid is formed by two mutually perpendicularly intersecting coordination axes

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where horizontal x-axis indicates evaluation of "performance" of PHL activities, but vertical y-axis - of "importance" (Figure 5.2). To find the crossing point of axes and position of evaluation of PHL activities in the coordinate system the average value of all importance scores and separately the average value of all performance scores are being calculated. The intersecting axes form four quadrants where each has its own meaning [34].

The PHL activities in quadrants of IPA grid are placed in the following way: 10 PHL activities' ratings are placed in quadrant B "Keep Up The Good Work", in quadrant C "Low Priority" 6 PHL activities' ratings are placed, 2 of PHL activities' ratings are placed in quadrant D" Possible Overkill", and in quadrant A "Concentrate Here" only 1 rating of PHL activities is placed. The biggest part of ratings of PHL activities is placed in two quadrants B and C (Figure 5.2). The total average of importance scores is 4.05 and for performance scores 3.57.

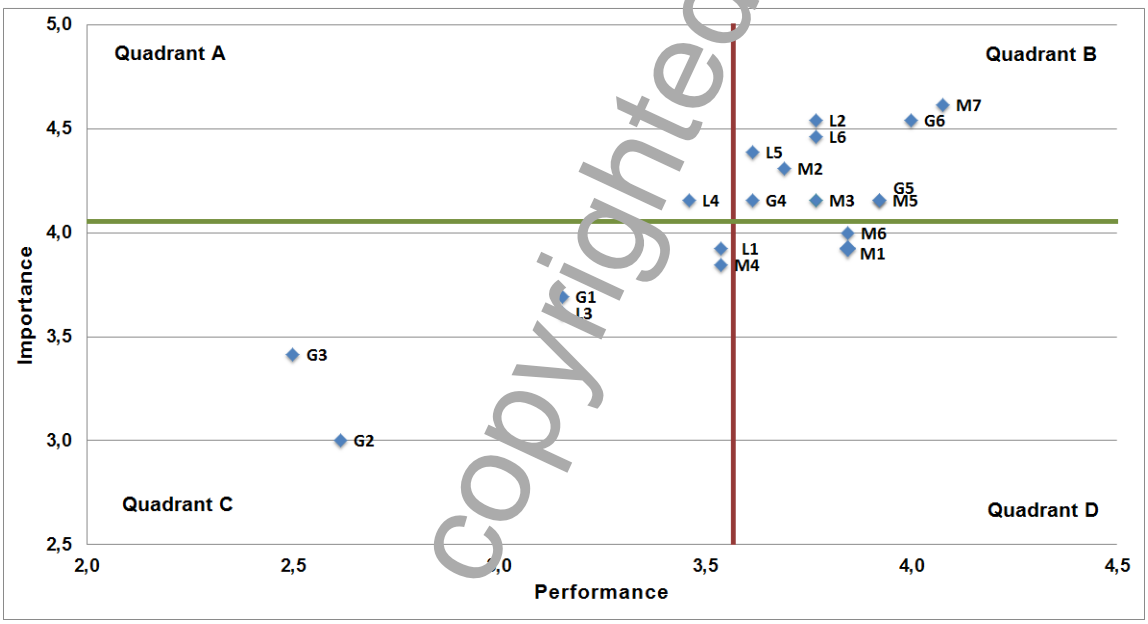

Figure 5.2. Evaluation results of activities for the persons at the highest level

The PHL activities, which on Figure 5.2 are located in quadrant B, show that they are important for enterprise representatives, as well as that in enterprises they are being used with the sense of responsibility. In quadrant B more than a half of all key activities for PHL are located. There can be also observed that activities that have received the highest average rating of importance have received also the highest rating of performance (M7 and G6). The remaining eight PHL activities have been evaluated as reasonably significant and the enterprises have also given high score to their performance level. The fact that all activities located in quadrant B are higher than the total average of importance and performance scores also should be taken into consideration. Location of PHL activities in quadrant B points out to a successful result and means that PHL should maintain their activities at the present level.

6 of 19 PHL activities are located in quadrant C, pointing out that in enterprises they have received low ratings and are less important to be given resources and be practically implemented. The PHL activities (G2 and G3) are to be regarded as express insignificant because they have received the lowest ratings. All PHL activities located in quadrant C are below the average importance and average performance levels. It would be an unjustifiable decision to concentrate on the investment of additional resources to improve the performance

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of activities in quadrant C because definite PHL activities have been evaluated as less important as compared with other – higher evaluated activities.

Both PHL activities located in quadrant D cannot be regarded as expressly overestimated from the representatives of enterprises (are not located in the central part of quadrant). However placement of activities (M1 and M6) on IPA grid shows that as compared with other 11 activities (in quadrants A and B) they both have been given smaller importance evaluations, nevertheless enterprises are investing their efforts (resources) and are performing them with responsibility.

The only PHL activity (L4) located in quadrant A is problematic. Although the activity has been evaluated as rather significant (another three activities have received similarly high but eight lower ratings) yet enterprises are not performing it with sufficient responsibility and have not given it sufficient resources, because average value of L4 performance is below the total average value of performance ratings. Location of PHL activity in quadrant A points out, that enterprises should pay it more attention and find appropriate solutions for its implementation.

As a result of organized survey a broad set of data was obtained giving an insight into characteristic activities of PHL. Construction of IPA grid helps to perceive and thus also to analyse and understand, which PHL activities in the opinion of SMEs representatives are more valuable and help to run the enterprise. Average values, standard deviation have been calculated for the obtained importance and performance ratings, as well as ranging of the gained evaluation has been made. Mutually comparing the average values of importance and performance scores of each PHL activity one can conclude that the surveyed enterprises are performing all PHL activities on lower level (performance) than they have evaluated their importance. The made conclusions provide essential information for testing the hypothesis put forth by the author.

5.5. Processing of evaluations of PHL activities by correlation and regression analysis

As a result of approbation of theoretically developed QSA method quantitative indicators have been obtained for the study of statistical relationships of which correlation and regression methods were used. Empirical data were obtained from the results of survey where 13 enterprises participated and evaluated 19 PHL activities (altogether 494 evaluations were analysed). In the survey each PHL activity was evaluated from two aspects – importance and performance, and a scale from 1 to 5 was used for the rating. The correlation method was chosen to determine whether an interrelation can be observed between importance and performance rating and whether these two variable values (X, Y) affect each other (if importance has received a higher score then the performance rating tends to increase or quite contrary – to diminish). Since it is necessary to find out relationship between two variables a simple linear regression is being used. After the construction of correlation diagram it was stated that for the modelling of relationships, we are interested in, a linear model is to be used. In correlation diagram importance is marked on x-axis and performance on y-axis. Respondents used a scale from 1 to 5 for the evaluation of importance and performance of each PHL activity (in the questionnaire). Thus linear relationship satisfies the research needs because the model will be used only with real positive numbers.

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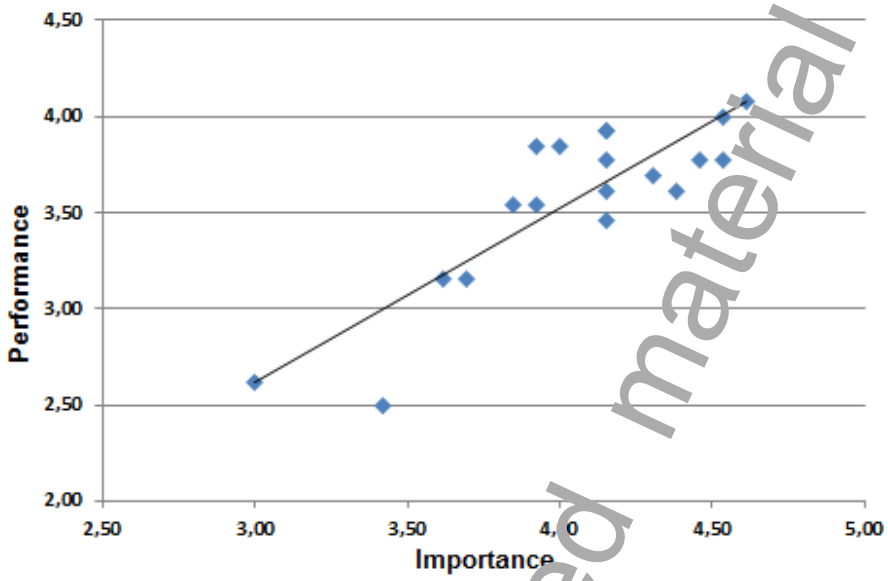

Figure 5.3. Scatter diagram and regression line: importance (Ox) and performance (Oy) evaluations of PHL activities

Data on population elements are not known; therefore parameters are evaluated by respective sample parameters. A simple linear regression model which describes the relationship between two variables is [45], [44]:

$$y_i = b_0 + b_1 x_i + e_i \quad (i = 1 \ldots n), \tag{5.1}$$

where y_i –the i th value of the dependent variable;
x_i – the i th value of the explanatory variable;
e_i – random error;
b_0 – the value of the intercept;
b_1 – the value of the slope;
i – the value for subject;
n – sample size.

Using the statistical data obtained by the survey the values of parameters b_0 and b_1 were established by the least squares method that minimize the sum of squared deviations e_i of observations [45], [28]. By the help of this method for the calculation of the intercept and the slope formulas [44] are being used:

$$b_1 = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2} \tag{5.2}$$

and

$$b_0 \frac{\sum_{i=1}^{n} y_i - b_1 \sum_{i=1}^{n} x_i}{n} \tag{5.3}$$

Carrying out calculation according to formulas (5.2) and (5.3) the value of the intercept b_o and the value of the slope b_1 were established.

$$b_1 = 0.899, \text{ but } b_o = -0.075$$

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According to formula (5.1) the linear regression model was gained:

$$y_i = 0.899x_i - 0.075,$$

where y_i – evaluation of performance of PHL activities;
x_i – evaluation of importance of PHL activities.

The obtained equation is graphically plotted into Scatter diagram (Figure 5.3) as a straight line. When the Scatter diagram has shown that there is relationship between importance and performance evaluations of PHL activities, the closeness of the relationship should be established. Since both variable values (importance and performance) are measured on an interval scale, for the calculation the Pearson's correlation coefficient is being used.

As a result of calculation [18] it was stated that correlation coefficient for the sample is:

$$r = 0.858$$

To make sure that the obtained Pearson's correlation coefficient can be used for the determination of relationship between two variables the obtained coefficient module is compared with critical value $r_{\alpha;n}$ ($\alpha = 0.05$). Since the coefficient module $|r| \geq r_{\alpha;n} = |0.86| \geq 0.533$ is larger than critical value conclusions can be made from the obtained correlation coefficient. The obtained correlation coefficient value r = 0.86 asserts that there is close relationship between the importance and performance evaluations of PHL activities.

To find out whether the obtained model predicts and characterises the relationship sufficiently well a coefficient of determination calculation [18] is done. When making calculation it was stated that determination coefficient of linear regression model is:

$$R^2 = 0.74$$

hence it can be concluded that in about 74% cases the performance scattering part can be explained by the influence of importance. The coefficient value is close to 1; it means that the prediction quality is good ($0.5 \leq R^2 < 0.8$).

Application of regression model in practice is possible in cases when any of 19 PHL activities is being evaluated only regarding importance (rating can vary from 1 to 5). According to the gained regression model it is possible to forecast the performance level of PHL activities in the enterprise. An example is the performance level of PHL activities where importance is estimated with „4". Assuming that x = 4, one can calculate that in case the enterprise representative has evaluated the importance of PHL activity by "4", the performance level of PHL activity will be y = 0.899 × 4 – 0.075 = 3.52.

The obtained regression model allows to predict the performance level of each PHL activity if the importance score of each respective PHL activity (19 altogether) is known.

To find out the relationship of importance and performance ratings of PHL activities gained, as a result of empirical research, calculation of regression and correlation indicators was done. A linear regression was gained allowing to model the level of performance of PHL activities depending on the importance level, using linear trend.

5.6. Scenarios and research method for the development of recommendations

The author in consultation with professionals in the field of quality management has identified several possible scenarios for the development of recommendations for leading persons of mechanical engineering sector. Having assessed the possible scenarios the author has chosen the following one: to carry out evaluation of 19 PHL activities identified as a

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result of analysis of three QS, using 10 questions developed for the enterprises of mechanical engineering, using the principles of Quality Function Deployment (QFD) method.

The author of the work uses QFD method to find out the relationship between the PHL activities (defined as a result of development of QSA method) and 10 questions of assessment of improvement amount (developed for the assessment of enterprises of mechanical engineering). The author believes that it is possible to find out these two relationships because: 1) validity of PHL activities has been tested and confirmed; questions for the assessment of improvement amount have been developed based on the approbated research results; 2) in both empirical researches positive results were gained, assessing both the importance and performance levels of PHL activities and expected improvements in the enterprises of mechanical engineering after certification of QMS according to the requirements of ISO 9001.

In order to implement the scenario for development of recommendations, a matrix is worked out where on horizontal rows 19 PHL activities are put, but vertical columns cover 10 questions, which the author has developed for the determination of improvement amount in enterprises of mechanical engineering. The matrix was prepared using *QFD Matrix Business Improvement Software*. Establishment of relationship between PHL activities and question of each improvement amount was performed by the author of the work, quality management representative of JSC *Sidrabe* and foreign expert in the field of quality management. For the development of recommendations QFD matrix results were used, combining the opinions of all three evaluators. Relationship between the PHL activities and questions assessing improvement amount were stated in 81% cases. The stated closeness of relationship characterises a very high correlation between implementation of PHL activities and possible improvement areas, therefore the gained results can be used for the development of recommendations for PHL of mechanical engineering.

Chapter 6. CONCLUSION AND RECOMMENDATIONS

The chapter reviews the objective of the doctoral dissertation, implementation tasks and research hypothesis, as well as states developed recommendations for small and medium enterprises of mechanical engineering and gives advices for further researches.

The objective of the doctoral dissertation was to develop a Method of Quality Systems Application to facilitate use of knowledge incorporated in quality systems in the management of small and medium enterprises of mechanical engineering. The defined problems concerning insufficient management skills incited the author to develop a research hypothesis – there is lack of management skills at small and medium-sized enterprises in Latvia.

Five tasks were stated to reach the advanced objective of the doctoral dissertation, which have been completely fulfilled during the research work and the work objective has been achieved.

One of the most significant developments of the doctoral dissertation is 19 PHL activities (Chapter 5, Table 5.1), which the author has established as a result of combined analysis of three QS (ISO 9001, EFQM Excellence Model and MBNQA Criteria for Performance Excellence). As a result of broad literature review the author has not found publications where previously any author would have suggested combined application of three QS, which would result in the identification of 19 PHL activities, therefore QSA method proposed by the author should be considered as original.

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Evaluation of the level of importance and performance of 19 PHL activities in SMEs in Latvia confirmed the hypothesis stated by the author. According to ratings given by the representatives of SMEs (Figure 6.1) it was established that none of 19 PHL activities has received higher score regarding performance than importance.

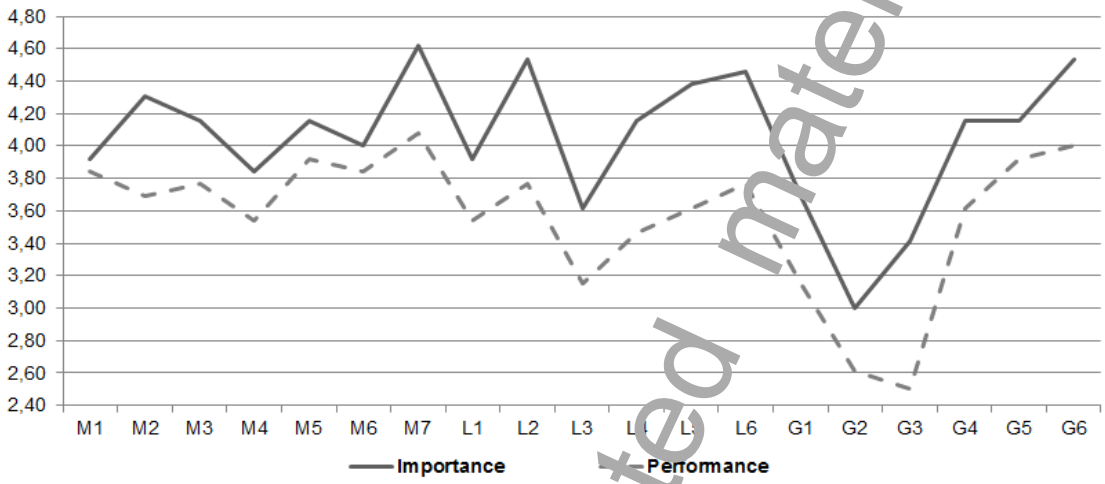

Figure 6.1. The gap between importance and performance evaluations of PHL activities

The fact that importance level of 19 PHL activities was evaluated higher than their performance level confirmed the hypothesis stated by the author – there is lack of management skills at small and medium enterprises in Latvia.

To promote improvement of management skills the work author advises the following recommendations for the persons at the highest level of SMEs:

1) To put into practice activities which the author has defined according to the developed QSA method that combines knowledges for the improvement of management skills incorporated in quality systems.
2) To apply detailed descriptions of PHL activities in order to carry out self-assessment of managerial activities implemented in the enterprise, and/or as an information source of new knowledge and ideas for the application of business improvement, thus taking into account requirements/ guidelines for the persons at the highest level of the enterprise, included in the quality systems.
3) In cases when the persons at the highest level of the enterprise encounter difficulties in rating the performance level of activities implemented by PHL, to carry out evaluation only of importance level of 19 PHL activities and, according to the mathematical model developed by the author to determine the performance level of 19 PHL activities depending on the score given to their importance.
4) To use evaluations of profesionals in the field of quality management, which has stated that implementing 19 PHL activities improvements are to be expected in all ten specific areas to enterprises of mechanical engineering, and it would significantly improves the quality of products, reduces the ratio of customer complaints of product, as well as optimize production/ processing processes.

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Scientific developments of the author can be useful for further theoretical and practical studies of activities to be performed by persons at the highest level. Further researches can be conducted to test the implementation of PHL activities in large companies or within any industrial sector. Principles of QSA method in the future can be applied for the analysis of requirements/criteria of other quality systems and to carry out assessment of application, thus developing combined use of quality systems.

The author of the work has carried out research on the assessment of improvement amount (after certification of the quality management system according to the requirements of ISO 9001) in small and medium-sized enterprises of mechanical engineering. The obtained research results show that it would be useful to carry out researches on the influence of a certified QMS also on other sectors and size classes of enterprises.

In the future a repeated research might be done in order to determine the proportion of enterprises in Latvia, which have certified quality management system according to the requirements of ISO 9001, in case if a complete register of certified enterprises is renewed /drawn up in Latvia, which at present is not available for the researchers.

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RESEARCH RESULTS AND FINDINGS

The doctoral dissertation proposes a solution how to improve the skills of persons at the highest level in the management of small and medium enterprises. As a result of research the following results and findings were gained:

1) New Method of Quality Systems Application has been developed and approbated, consisting of four steps and consequently performed tasks. Contrary to the accepted use of one quality system a synergic use of three different systems is proposed, ensuring mastering of wider enterprise management skills. QSA method proposed by the author is suitable for small and medium enterprises of mechanical engineering and any other sector.

2) Applying statistical observation, grouping and sampling, a method has been developed and it has been stated that in Latvia the biggest number of certified QMS are in small (42%) and medium (39%) enterprises. The third most active group is large enterprises (constitute 14%), but the least interested in certification of QMS are micro enterprises (5%). The research results show that in Latvia the number of certified QMS compared to the number of economically active enterprises is comparatively small (about 1%), but it does not differ from the situation in other Baltic states where the situation is similar.

3) According to the developed method the proportion of enterprises in mechanical engineering by size-classes which have the certificate of conformity to ISO 9001. The gained results show that situation in mechanical engineering sector is similar to the general situation in Latvia – the biggest number of ISO 9001 certificates is in the group of small and medium enterprises. When comparing the proportion by enterprise size-classes in Latvia and in mechanical engineering sector, it was stated that it is different – in mechanical engineering sector the biggest part is constituted by medium enterprises (59%) and nearly one third is made by small ones (29%). The remaining part is constituted by large (8%) and micro size (4%) enterprises.

4) According to the results of statistical data processing one can conclude that 6% of all enterprises, which in Latvia have certificate of conformity with requirements of ISO 9001, are constituted by the enterprises of mechanical engineering. Comparatively it is 3.5 times less than on the average in the world where enterprises of mechanical engineering have moved forward to the leading five according to the sector classification. It shows that in enterprises of mechanical engineering certification of conformity with requirements of ISO 9001 in the world generally is widely spread and should be characterised as high, while in Latvia it should be characterised as low.

5) As a result of empirical researches it was stated that in SMEs of mechanical engineering sector in Latvia after QMS certification 6 – 15% large improvement amount is possible in ten areas of business. A possibility to master new foreign markets is the highest evaluated improvement, and then follows a possibility to improve the quality of products, to reduce the ratio of customers' complaints and ratio of produced defects. According to the data given by enterprises one can conclude that in all ten studied areas of business improvements are to be expected after certification of QMS, because in no area the most often given amount of improvements was 0% (no improvements).

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6) Four QSA method steps have been developed – 1) selection of quality system, 2) analysis, 3) synthesis and 4) interpretation. Each step of QSA method consists of several tasks – altogether 14 implementation tasks have been developed. Three types of PHL activity have been established within the QSA method for AQS: management (M), leadership (L) and governance (G). As a result of performed analysis new types of PHL activities are not proposed, but key activities has been stated for each type of activity, which were defined as a result of a combined analysis of three QS. According to QSA method and its implementation tasks altogether nineteen key activities that are to be implemented by the enterprise's PHL have been defined.

7) 19 PHL activities, that have been defined as a result of the research, can be used by the enterprises' persons at the highest level not only in Latvia, but also in other countries, because 19 PHL activities, which have been established as a result of combined application of three quality systems, has been verified through international researches by other authors.

8) The technique for the approbation of QSA method results have been developed for the evaluation of the importance and performance level of 19 PHL activities. The technique has been specially designed for the needs of research and they allows simultaneously to characterise the level of understanding of enterprises' representatives of the importance of PHL activities, as well as demonstrates the level of activities implementation and application skills in enterprises.

9) By collecting and assessing evaluations given by SMEs on the importance and performance levels of 19 PHL activities the research hypothesis was tested. Comparing mutually average values of importance and performance of each PHL activity as well as average values of all PHL activities one can conclude that the surveyed enterprises are carrying out all PHL activities on a lower level (the average value 3.57) than they have assessed their importance (the average value 4.05). The hypothesis stated by the research was confirmed because there is difference between the actual and expected level of managerial performance in SMEs in Latvia.

10) As a result of approbation of QSA method quantitative data were obtained and it was stated that activities of PHL importance and performance levels closely correlate ($r = 0.86$). Since the prediction quality of linear regression model is to be characterised as good ($R^2 = 0.74$) then this model can be applied in cases where 19 PHL activities have been evaluated only regarding one factor – importance.

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