

**Robert KŁOS, Beata FABISIAK, Jasna HROVATIN, Hon Keung Tony NG**

## **RELIABILITY AND WARRANTY ISSUES IN THE DESIGN AND PRODUCTION PRACTICE OF SELECTED POLISH AND SLOVENIAN FURNITURE-MANUFACTURING COMPANIES**

*Reliability and quality issues are of crucial importance for both customers and manufacturers operating in a highly competitive marketplace. The aim of the study was to recognize attitudes towards product reliability in the furniture industry. The results are presented of the research conducted in 75 Polish and Slovenian furniture companies, focusing on the manner in which enterprises determine the length of the warranty period and which tools they implement to evaluate the reliability of the furniture construction. The data was collected through direct interviews and surveys. The high level of recognition of reliability and quality as key success factors for the next 5-20 years in the furniture industry was observed. A positive correlation was explored between the size of the enterprise and the existence and use, during the design process, of a database detailing structural failures. A coexistence of variables was found connected with the use of a failures database, an implemented, integrated CRM (Customer Relationship Management) system and the offering of an extended warranty period. The results of the study confirm the necessity and importance for furniture-manufacturing companies to consider reliability and warranty issues in their industrial practice.*

**Keywords:** reliability, warranty, furniture manufacturing companies

### **Introduction**

Issues concerning the reliability of products and services play an important role in many branches of industry, ranging from water-supply grids, aviation, and construction engineering, to computer systems and the automotive industry. It is essential when the improved design of new products is being considered [Dhillon 1999; Yang and Cekecek 2004; Arvidsson and Gremyr 2008]. Recently,

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Robert KŁOS ([krobert@up.poznan.pl](mailto:krobert@up.poznan.pl)), Beata FABISIAK✉ ([beata.fabisiak@up.poznan.pl](mailto:beata.fabisiak@up.poznan.pl)), Department of Furniture Design, Faculty of Wood Technology, Poznan University of Life Sciences, Poznań, Poland; Jasna HROVATIN ([jasna.hrovatin@fd.si](mailto:jasna.hrovatin@fd.si)), Department of Interior Design, Faculty of Design, Associated Member of the University of Primorska, Trzin, Slovenia; Hon Keung Tony NG ([ngh@mail.smu.edu](mailto:ngh@mail.smu.edu)), Department of Statistical Science, Southern Methodist University, Dallas, Texas, USA

however, there has been increasing interest in the question of reliability in the furniture industry [Gremyr et al. 2003; Smardzewski 2005, 2009; Kłos and Fabisiak 2010]. Attention has been focused on the potential application of the theory of reliability in the furniture-design process [Kłos and Fabisiak 2013a] and in the operations of furniture-manufacturing enterprises [Kłos and Fabisiak 2013b].

Reliability is a crucial characteristic when it comes to determining the commercial success of a product and is an essential element in the competitive strategy of many enterprises [Murthy 2006, 2007; Blischke et al. 2011; Kłos and Fabisiak 2013a]. Furthermore, it is of great importance for both manufacturers [Vickery et al. 1997] and consumers [Sinclair and Hansen 1993; Chien et al. 2005; Šalgovičová and Urdziková 2009] of furniture. This is because furniture should not only be visually attractive, but should also conform to adequate safety standards. Negligence with respect to reliability concerns may result in an increased number of products that are unsuitable for use, a deterioration in the quality of the manufactured items and consequently the reduced competitiveness of the pieces of furniture on the market.

In order to facilitate the design, a works specification is provided for the quality of the joints used in a given piece of furniture, resulting in its reliability. The reliability of an item is a property determined by values related to specific measures characterising the potential of this item to meet the requirements [Migdalski 1992]. Reliability can be established on the basis of information about whether a particular item has been damaged within a specific time period or whether it failed after the performance of a specific task.

Furniture manufacturers do not typically assume the probability of the failure-free operation of a final product within a specific time period. The liability legislation accurately determines the obligations of the producer in relation to the buyer in terms of a warranty service, i.e., the repair of defects or the potential replacement of the merchandise with a defect-free item. As stated by Migdalski [1982], the length of the warranty period should be adjusted so that failures occurring in the final product are revealed during that period with a probability close to one. Thus, it plays the role of a long-term test and should approximately cover the time period during which all defects occur. An intuitive determination of the warranty period by the constructor may be replaced by a statistical analysis and a series of investigations.

The issue of the reliability of joints and furniture, as demonstrated so far, has been discussed in only a limited number of publications. The determination of the time and the probability of failure for a complete piece of furniture construction or one of its elements, based on subjectively assumed safety indexes and a safety margin, should not be the basis for an inference about the durability of a piece of furniture or its components. It is obvious that only the determination of specific reliability characteristics can provide the basis for conclusions on the durability and safety of furniture subject to use.

Taking the above into consideration, the aim of the study was to acquire and compare data concerning the attitudes towards reliability and warranties in Polish and Slovenian furniture-manufacturing companies, as well as how knowledge concerning the reliability of items of furniture is used in their design and manufacturing practices. Moreover, an additional objective of the research was to investigate the demand by Polish and Slovenian entrepreneurs for the development of a tool to enable the warranty period to be determined for an item of produced furniture.

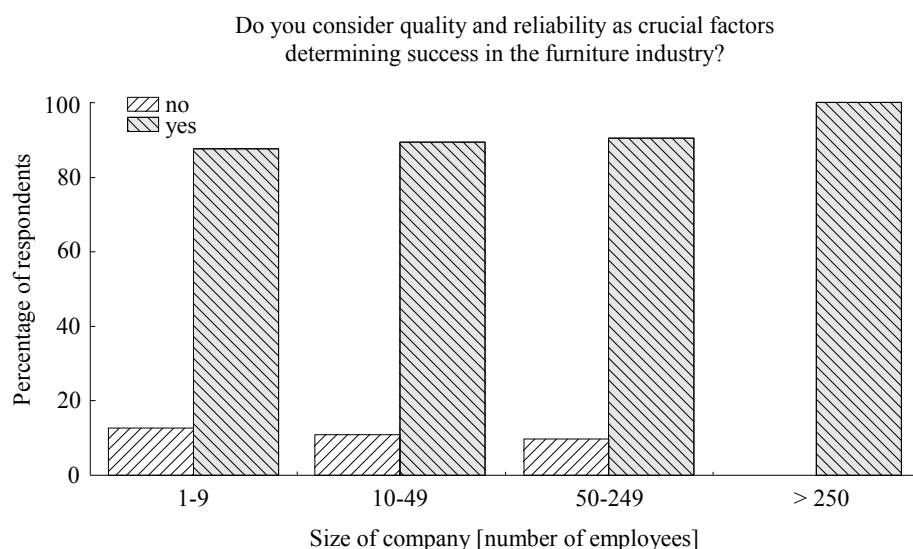
## **Methodology**

The decision was made to collect the relevant data using questionnaire studies and direct interviews. The assumed population size amounted to 100 furniture factories located in Poland and Slovenia. Additionally, more detailed direct interviews were conducted with a group of 30 enterprises manufacturing case-type furniture which were interested in the issue of product reliability. This group consisted of 19 Polish furniture-manufacturing companies and 11 from Slovenia. The collected data were coded and then subjected to a comprehensive statistical analysis with the use of the STATISTICA 10.0 software. The data analysis was performed by applying the statistical grouping method, taking into account the division of the units, based on the criteria of the country of origin and the size of the enterprise. Stratified sampling, with respect to the size of the company, was used to make it possible to explore the hypothesis that company size resulted in a greater awareness of the need to ensure the quality and reliability of the pieces of furniture produced. Moreover, the sampling, taking into account the location of the company, was conducted, to discover whether there were differences between the attitudes of the furniture manufacturers in the countries analysed. In addition, a cluster analysis was conducted. The method developed by Ward [1963] was applied as an agglomeration algorithm, which made it possible to estimate the distances between the clusters using the analysis-of-variance approach, as it aimed to minimise the sum square of the deviations within the clusters. Moreover, an analysis of correspondence was used to investigate the coexistence of variables concerning such characteristics as, for example, the size of the enterprise, the collection and use of a database of failures occurring in the designed and manufactured products, the existence of a design department, the integrated CRM system implemented by the enterprise or the offer of an extended warranty period for an item of furniture.

## **Results**

Taking into consideration the percentage of returned questionnaires, their completeness and the number of direct interviews performed, it was decided to conduct further analyses based on the data coming from 75 units.

When analysing the attitudes of furniture manufacturers towards quality, reliability and warranty issues, it was decided to first assess the importance of these problems in the economic activity of the investigated units. The results of these investigations showed that over 90% of managers from the companies analysed declared that in their opinion the quality of the products and their reliability were two of the most important factors determining success in the furniture industry in the next 5-20 years. Moreover, it should be emphasised that the percentage of companies agreeing with this opinion increased with the size of the enterprise, and in the case of units employing over 250 workers, the figure was as high as 100% (fig. 1). The results also indicated a great deal of interest in this subject and the importance for the furniture-manufacturing companies under analysis of issues connected with the reliability of products.

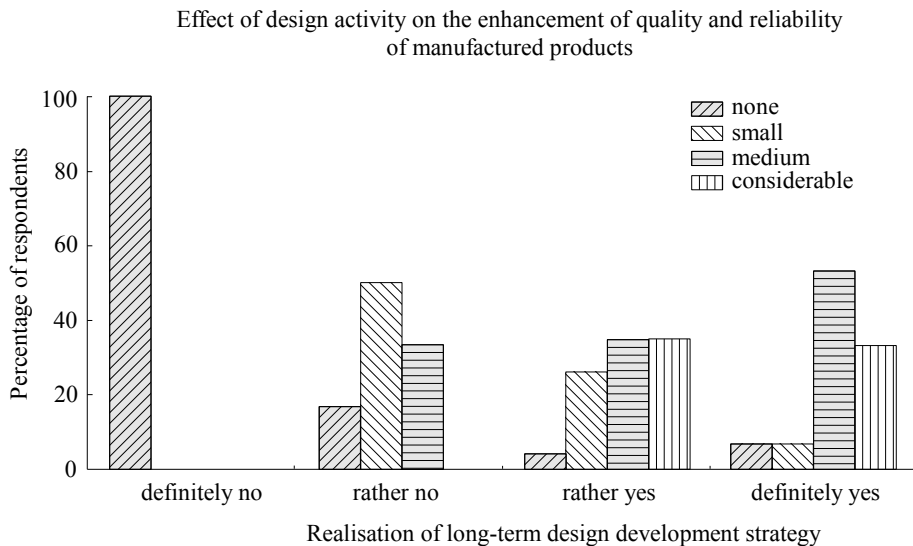


**Fig. 1. Opinions of furniture manufacturers concerning the quality and reliability of products as key success factors in the furniture industry in the next 5-20 years in terms of company size**

Source: Own elaboration based on empirical studies conducted.

The tremendous importance of the attention to the quality of manufactured products is associated, e.g., with the long-term vision of an enterprise's design development, and a consideration of issues connected with reliability and quality, even as early as during the stage of product design. In those companies in which design was not seen as a crucial element, no significant effect of the design activity on enhancing the quality and reliability of the manufactured products (fig. 2) was observed. However, the situation was completely different in those companies in which the managers stressed the important role of design in the development of the enterprise and its application in many different areas

of the organization. They emphasized that over the previous 3 years, prior to the study, the incorporation of reliability considerations during the designing of new products and a greater awareness of new-model design contributed to the improved quality of the products manufactured. Such an opinion was expressed by as many as 86% of the managers of those companies in which the design activity was of key importance, indicating that the impact of the above-mentioned actions on product quality and reliability was medium (53%) or considerable (33%).

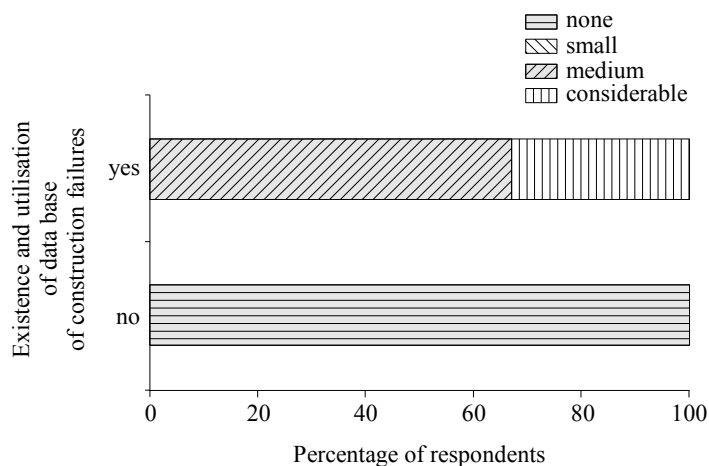


**Fig. 2. Opinions of interviewed furniture manufacturers concerning the effect of design activity on the increased quality and reliability of manufactured products depending on the realisation of a long-term design development strategy by the enterprise**

Source: Own elaboration based on empirical studies conducted.

Identifying the crucial influence of design activity on the enhancement of the quality and reliability of manufactured products was related to the existence and utilisation of data from a database of failures during the process of new product design. Companies that did not collect information on structural failures occurring in their products, obtained, for example, during the complaints process, indicated that industrial design had no effect on the improvement of the quality of the products manufactured (fig. 3). The situation was completely different in the case of enterprises using such data. All of the companies analysed which collected and processed information on the failures that occurred in their manufactured furniture items evaluated the effect of the design activity on the improvement in product quality and reliability as either medium or

considerable (67% and 33%, respectively, for companies having and using databases of failures).



**Fig. 3. Opinions of furniture manufacturers under analysis concerning the effect of design activity on the improvement of quality and reliability of manufactured products in terms of the existence and usage of a database of structural failures within the company**

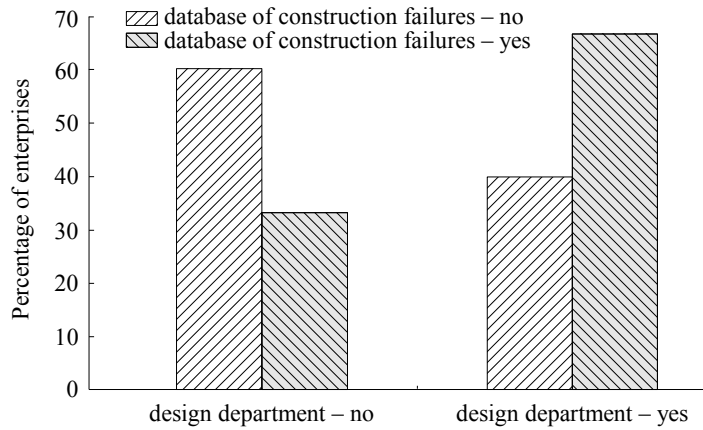
Source: Own elaboration based on empirical studies conducted.

A comparative analysis of the utilisation of information on failures previously occurring in manufactured products during the design process in Polish and Slovenian companies showed that the percentage of companies with such a database was similar in Polish and Slovenian enterprises, amounting to 75-80%.

The results of the analyses also showed that those enterprises that had a design department, more frequently than those with no such organisational unit, had and used a database of failures. However, it was interesting that 40% of the companies with a design department did not collect or process information on the structural defects occurring in their products (fig. 4).

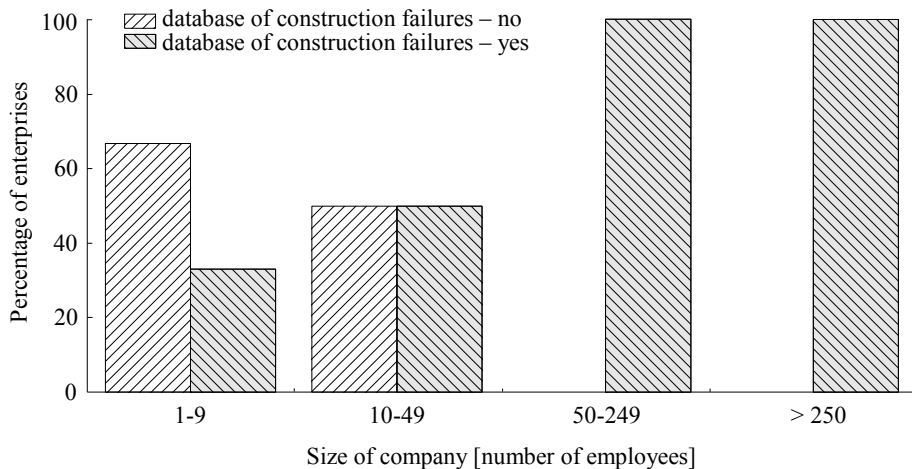
A graphical representation of the statistical clustering conducted indicates that the existence of a database of failures in an enterprise is related to its size (fig. 5). It was found that only 33% of the microenterprises and 50% of the small companies collected information on structural defects. In contrast, this dependence was much more advantageous in medium-sized and large enterprises, where the figure was 100%.

A chi-square independence test was conducted for the discussed variables. Verification was provided for the zero hypothesis, defined as follows:  $H_0$ : variable X (the existence of a database of failures in an enterprise) and variable



**Fig. 4. Enterprises under analysis in terms of the existence and utilisation of a database of failures depending on the presence of a design department in the enterprise**

Source: Own elaboration based on empirical studies conducted.



**Fig. 5. Enterprises under analysis in terms of the existence and utilisation of a database of failures depending on the size of the enterprise**

Source: Own elaboration based on empirical studies conducted.

Y (the size of the enterprise) are independent, against an alternative hypothesis;  $H_1$ : variables X and Y are not independent. The results of the test indicated that this dependence was significant at  $p = 0.00745$  ( $\chi^2 = 11.9792$ ). Thus, it is acceptable to reject the zero hypothesis concerning the independence of the variables analysed and accept the alternative hypothesis regarding the existence of a relationship between the presence of a database of failures and the size of the enterprise. The considerable strength of the dependence between the

analysed variables was indicated by both the value of the coefficient of contingency ( $C = 0.5852$ ) and V Cramer's coefficient ( $V = 0.7217$ ). The strength and the positive direction of the discussed dependence are also reflected in Kendall's  $\tau$ -c coefficient, which was 0.4915 and indicated a positive correlation between the analysed variables (table 1).

**Table 1. Results of chi-square independence test for the following variables: existence of a database of failures in enterprise and size of enterprise**

	$\chi^2$	The number of degrees of freedom	The level of significance
$\chi^2$ Pearson	11.9792	Df=3	p=0.00745
Contingency coefficient	0.5852		
V Cramer's coefficient	0.7217		
Kendall's $\tau$ -c coefficient	0.4915		

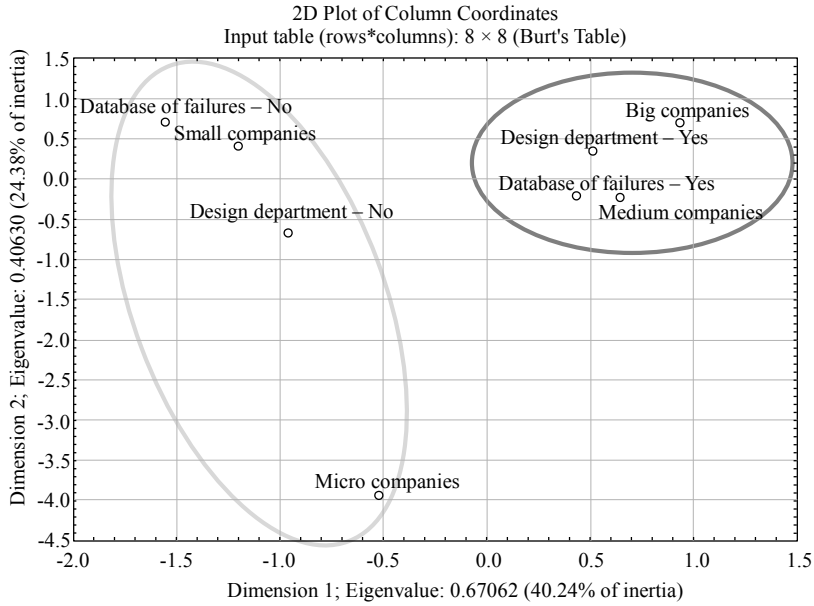
Source: Own elaboration based on empirical studies conducted.

The coexistence of individual variants of the variables under analysis, along with the additional variable "the existence of a design department in the structure of the enterprise", was investigated using the analysis of correspondence. The results were then verified using a cluster analysis.

The decision was made to apply a two-dimensional solution space. A graphical representation of the results of the analysis of the correspondence indicates differences between the two groups of enterprises, depending on their size, the presence of a design department in their structure and the use of a database of failures (fig. 6). The first group was composed of micro-enterprises and small companies with no design department, and which, more frequently than the enterprises from the other group, did not use databases related to structural defects. The other group comprised medium-sized and large companies, which incorporated a design department in their structures and which used information contained in the database of failures during the design process.

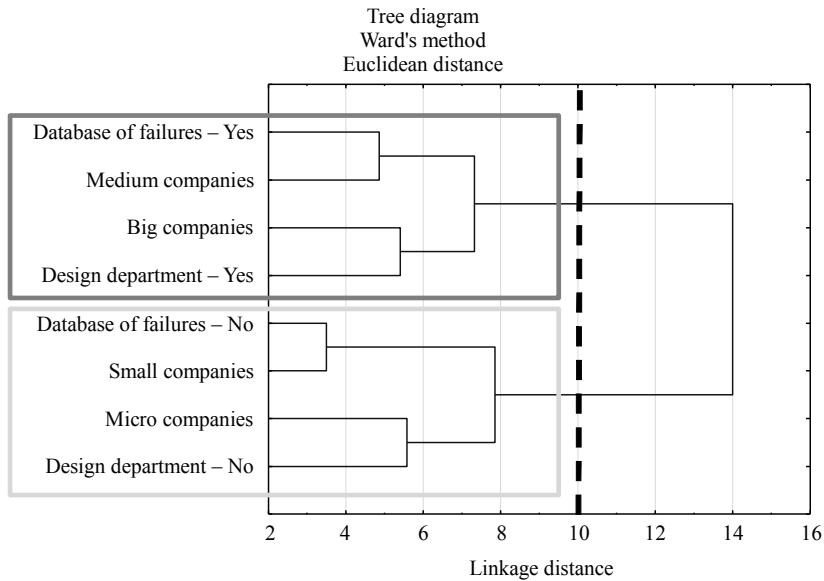
In order to verify the character of the connections between the individual variants of the variables under analysis, the hierarchical classification of the cluster analysis was conducted using the Ward method (fig. 7). The results of the analysis of correspondence were confirmed, identifying two groups of characteristics that coexist with respect to the existence of a design department in the companies, the size of the enterprise and the collection and utilisation of information concerning failures occurring in the designed and manufactured products.





**Fig. 6. A graphical representation of the results of the analysis of correspondence for the following variables: size of enterprise, existence of a design department in company structure and use of a database of failures**

Source: Own elaboration based on empirical studies conducted.

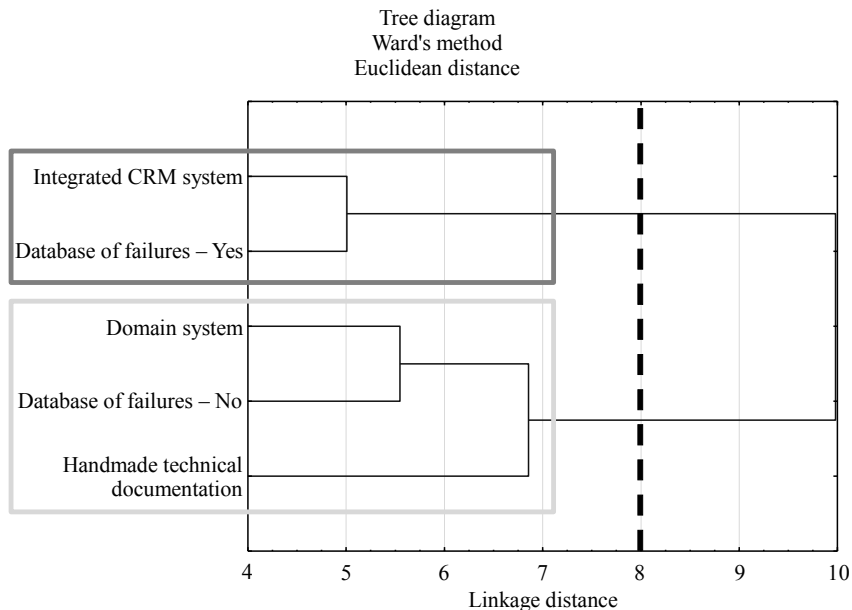


**Fig. 7. Results of a cluster analysis for the following variables: size of enterprise, existence of a design department and use of a database of failures**

Source: Own elaboration based on empirical studies conducted.

A study by Kłos and Fabisiak [2013b] conducted on a sample population of Polish furniture enterprises also showed a relationship between the existence of a database of failures and an implemented integrated CRM system in the enterprise. This was obviously connected with an integration of all the data, including design issues, within the enterprise. This tendency was also confirmed for the international group of enterprises under examination. For the appropriate definition of connections between the discussed variables, a hierarchical classification of the cluster analysis was applied using the Ward method.

The results of the cluster analysis showed that two distinct main groups existed in the investigated population of enterprises (fig. 8). The results obtained made it possible to precisely identify the enterprises that were similar in terms of dependencies between the presence of a database of the failures occurring in the structure of the furniture manufactured and the method of collecting and processing the data concerning the products designed.



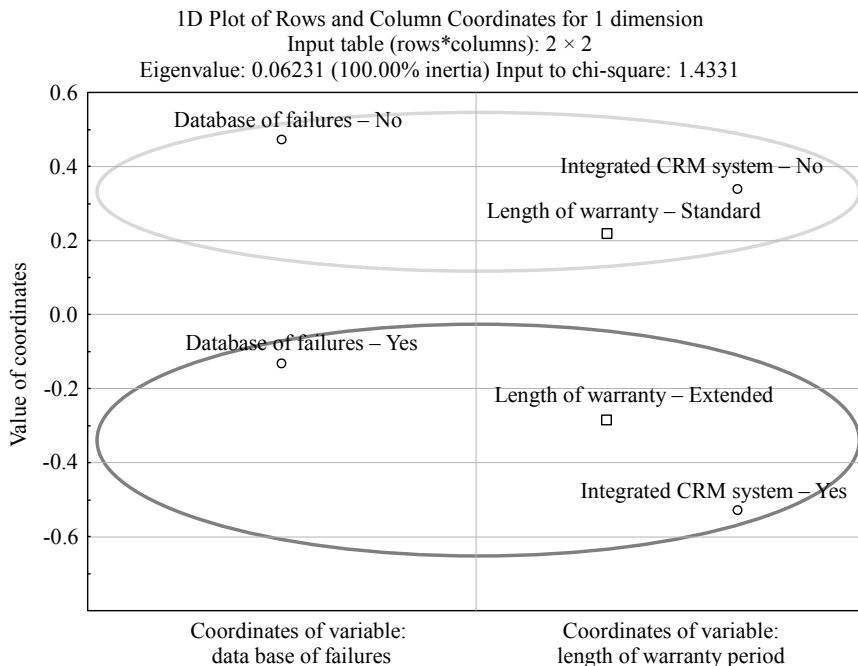
**Fig. 8. A graphical representation of the results of the cluster analysis for the following variables: existence of a database of failures and method of collecting and processing information about the designed products**

Source: Own elaboration based on empirical studies conducted.

An important aspect when assessing the attitude of entrepreneurs towards the reliability of their manufactured products should be related to issues concerning the warranty for the designed and manufactured products. For this reason it was decided to conduct an analysis, for example, of the length of the warranty period offered by the enterprises. The majority of the Polish companies retained the

statutory minimum warranty period, meaning that the manufacturer remains liable for defects in the product for two years. However, some of the companies surveyed (27%) offered an extension to this period, depending on the quality of the parts used or the employment of a team of assemblers certified by a given company for the installation of furniture [Kłos and Fabisiak 2013b]. The situation was similar in the case of the Slovenian companies, with over half (62%) offering a 2-year warranty period and 38% of the enterprises offering a 3-year warranty. Some of the companies offered an extension to the warranty period when more advanced parts were incorporated into the furniture.

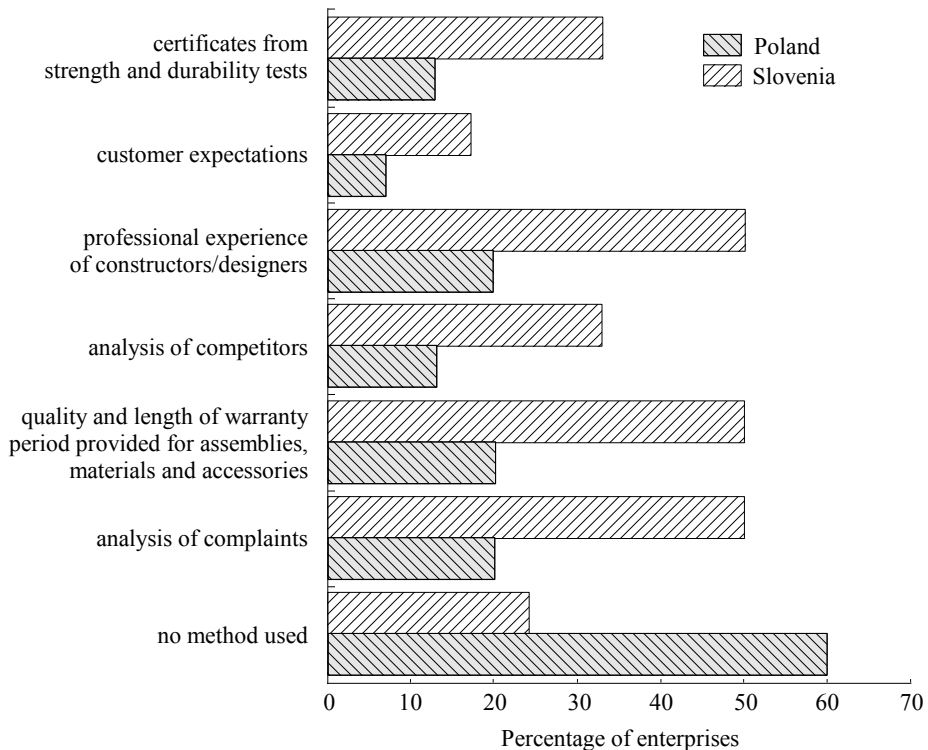
Moreover, the analysis of correspondence was conducted to provide a more comprehensive illustration of the relationships between the variables concerning the existence of a database of failures, the processing method and the data accumulated on the designed products, and the length of the warranty period offered by the company. A presentation in a one-dimensional space of the coexistence of the variants of the variables under analysis made it possible to explain 100% of the total inertia, and thus this was used to present the results (fig. 9).



**Fig. 9. Presentation of results of analysis of correspondence for variables determining existence of a database of failures and length of warranty period offered by enterprise for manufactured products; additional points: method of collecting and processing data on designed products**

Source: Own elaboration based on empirical studies conducted.

An exceptionally important issue that needs to be analysed is the method used to determine the length of the warranty period for manufactured products when it differs from the legally binding period of 2 years. The results of the study showed that for more than half of the Polish enterprises examined (60%), the length of the warranty period for furniture was not defined in any specific manner. In addition, it was reflected in the fact that the shortest warranty period required by law was often offered [Kłos and Fabisiak 2013b]. In the case of the Slovenian companies, this percentage was much lower, only 24% of the enterprises do not use any form of assessment, justifying the statement that the construction of the designed furniture was a durable, and appropriately designed system. Figure 10 presents a comparison of the various methods for determining the warranty period applied by the Polish and Slovenian enterprises. It should also be emphasised that the Slovenian companies, more often than the Polish companies, used information from the strength-testing of new furniture models and the expertise of the engineers and designers employed.



**Fig. 10. Basis for estimation of warranty period provided for manufactured furniture**

Source: Own elaboration based on empirical studies conducted.

It is important to note that none of the entities analysed applied any type of calculation to specify the length of the warranty period. This indicates a gap in the transfer of knowledge from university/research units to industrial practice which would support utilisation of the potential of the data collected and processed by companies, and concerning the reliability of furniture construction in order to determine more reliably the length of the failure-free life of a given item.

As a consequence of the lack of objective and tangible methods used to determine the warranty period in the design and production practice of the furniture companies, it was observed that the enterprises under analysis very often used several methods simultaneously in order to determine the length of the warranty period for manufactured models of furniture.

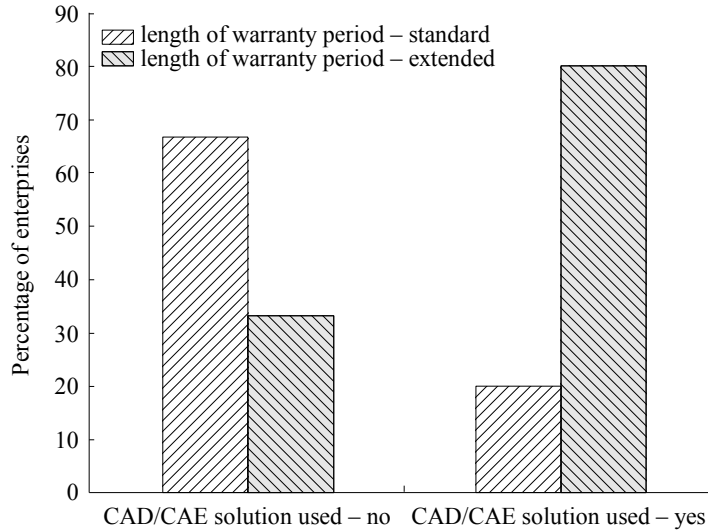
It shows that furniture companies do not use tools that would enable them to clearly determine the warranty period. Therefore, there is a need to develop a mathematical model of the reliability of furniture construction, which would form the basis of such a tool. It could solve the problem described above. The use of such a tool by furniture manufacturers would enable companies to determine the warranty period in a reliable manner and extend it due to certain actions during the design phase.

Analysis of the data obtained in the study of an international group of enterprises showed a dependence between the application of a CAE/CAD programme during the design process and the offer of an extended warranty period to consumers. As many as 80% of the companies using software-aided engineering and design activity (CAE/CAD) offered an extended warranty period (fig. 11).

Furthermore, an additional aim of the research conducted was to determine demand on the part of entrepreneurs for a tool to establish the reliability of the construction of case-type furniture and to calculate the warranty period. Both the Polish and Slovenian furniture manufacturers were enthusiastic about the solution presented. Over 70% of the enterprises investigated in both countries expressed the opinion that the application would be useful in their design and production practice, while almost 60% expressed their willingness to participate in testing of the new tool.

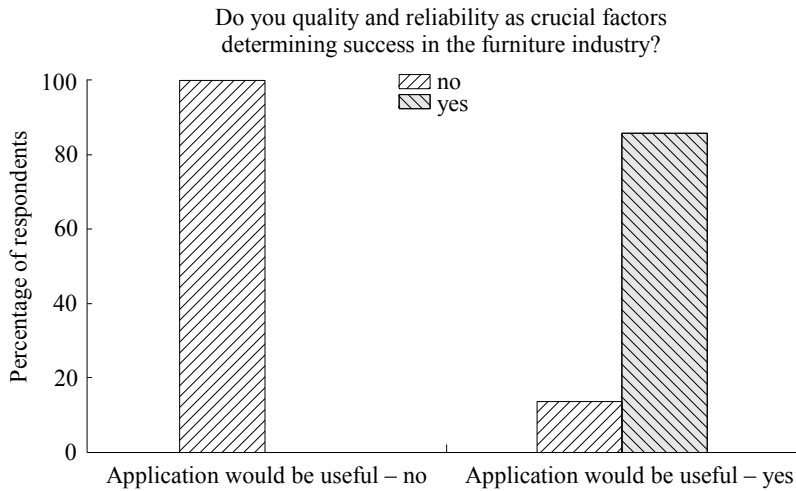
It should also be emphasized that the usefulness of the application was mainly mentioned by those enterprises identifying the quality and reliability of products as key factors which will determine success in the furniture industry in the very near future (fig. 12).

Similar results were obtained when investigating the willingness of entrepreneurs to participate in testing of the new tool (fig. 13).



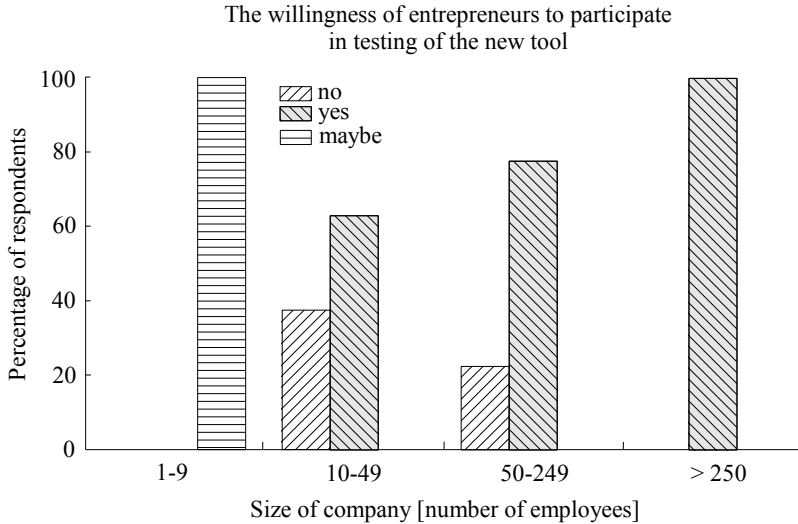
**Fig. 11. Structure of enterprises in terms of length of warranty period offered depending on application of a programme aiding engineering and design activity**

Source: Own elaboration based on empirical studies conducted.



**Fig. 12. Opinions of managers concerning the usefulness of application to determine reliability in the case of furniture construction and to calculate length of warranty period depending on recognition of quality and reliability of products as key factors in development of furniture industry**

Source: Own elaboration based on empirical studies conducted.



**Fig. 13. Opinions of managers concerning their willingness to participate in testing of new tool to determine furniture reliability and calculate period of failure-free operation, depending on size of enterprise**

Source: Own elaboration based on empirical studies conducted.

The large number of the enterprises interested in a solution which would enable them to determine furniture reliability and calculate the period of failure-free operation, both among Polish and Slovenian companies, indicates the significant role of this issue in the manufacturing activity of furniture-producing enterprises.

## Conclusions

The results present the level of awareness and the level of use of information concerning the reliability issues of designed and manufactured products in the design and manufacturing practice of furniture companies.

Based on the investigations conducted, the following conclusions were drawn:

1. The analyses showed a high level of recognition of reliability and quality as key success factors in the next 5-20 years in the furniture industry. The importance for the enterprises under analysis of issues connected with the reliability and quality of designed and manufactured products increased with the size of the enterprise. The larger the company, the greater the probability that it would consider quality and reliability as key success factors in the furniture industry.

2. A positive correlation was observed between the size of the enterprise and the existence and use of a database of structural failures during the design

process. All of the companies analysed employing more than 50 workers (medium-sized and large companies) collected information on structural failures which occurred in the designed and manufactured products. Additionally, it was found that companies with design departments within their organisational structure frequently followed a consistent, long-term design development strategy.

3. A coexistence of variables was found connected with enterprises having a database of failures, as well as an implemented, integrated CRM system and the offer of an extended warranty period for designed and manufactured furniture.

4. No significant differences were found between the selected Slovenian and Polish enterprises when taking into consideration the level of awareness of the managers concerning the importance of issues related to the quality and reliability of manufactured furniture, and the use of information regarding product reliability in the design and manufacturing practice. In contrast, a difference was found for Slovenian companies in their more frequent use of information coming from the strength testing of new models (38%), and the professional experience of the engineers and designers employed (50%) when estimating the length of the warranty period.

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## Acknowledgements

The issues examined constitute part of the project: StarDust of the Baltic Sea Region Programme 2007 – 2013: The Strategic Project in Trans-national Commercial Activities in Research & Innovation, Clusters and in SME-Networks.

This work was part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument).



Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)



BSR STARS

Innovation in the Baltic Sea Region



*Submission date: 22.02.2016*

*Online publication date: 23.03.2017*