Knowledge Sharing Model for Integrated Development of Products in Machine-building (Results of the Exploratory Study)

Diana Antonova[a], Svilen Kunev[b] and Irina Kostadinova[c]
Department of Management and Social Activities, University of Ruse "Angel Kanchev", 8 Studentska str., Ruse, Bulgaria

Keywords: Knowledge Creation, Exchange and Transfer, Shared Supplier Knowledge, Process Performance, Core Competencies, NPD, Value for Consumers.

Abstract: Every industrial enterprise should apply effective knowledge creation and transfer as an instrument for increasing its competitiveness in strategic, long-term horizon. It makes the research of different techniques adopted by companies for turning knowledge into a competitive advantage extremely important both for academics and practitioners. Research works that analyse the key characteristics of creation of new knowledge, exchange and knowledge transfer put focus mainly on activities for research and development (R&D) in knowledge intensive industrial sectors, such as biotechnologies and information and communication technologies. In this paper, we explore the knowledge creation, exchange and transfer in the traditional mechanical engineering in Bulgaria, Germany, Japan and the USA.

1 INTRODUCTION

The capabilities of the companies to develop products stem from their skills to create, disseminate and implement knowledge in the various phases of the innovation process (Kunev et al., 2012).

The majority of studies is directed to the issues of integration of activities (Griffin, 1997; Shah at al., 2009; Kostadinova et al., 2019; Kunev, 2010; Ruskova et al., 2018) and the phases in the development of new products (Vitliemov et al., 2001; Iliev et al., 2018; Zlatarov et al., 2018) as opposed to the issues of integration of knowledge (sharing).

This paper is based on the integration (sharing) of knowledge in the new product development – IKNPD, (Orstavik, 2004). Empirical research of IKNPD (Todorova et al., 2011; Stoycheva et al., 2016; Antonova, Stoycheva, 2018) prove the importance of organisational integration for the competitive advantage of the industrial enterprise through a correlation between the interaction patterns and the opportunities for success. Such collaborative efforts contribute to marked improvements in the innovation activities of industrial enterprises and lead to good market results (Stoycheva et al., 2018). Although there is no doubt about the importance of shared knowledge, concerning NPD, it is hard to create such useful knowledge sharing spontaneously, due to the different cognitive worlds of departments and individuals and the „basic information", which consists essentially of what must be separated from the specific content, particularly in the thematic setting of IKNPD. Among the seven phases of the IKNPD process – idea, concept elaboration, design of the system, testing and improvement, production, commercialization – the first and the last phase include concept development and precede the design of the system (Antonova, et al, 2018). This is the level, at which knowledge sharing should be executed among the development teams (Ruskova, 2012). An important aspect of knowledge access and exchange are also the user requirements, supplier capacity and core competences (Orstavik, 2004).

Multifunctional coordination is enhanced through increasing the in-depth knowledge with every function. In reality, there is no practical evidence that knowledge integration improves IKNPD results. In order to summarize the preliminary study on the topic, this study analyses the content of knowledge integration and the eventual reasons for correlation of

[a] https://orcid.org/0000-0002-6060-6974
[b] https://orcid.org/0000-0001-8726-935X
[c] https://orcid.org/0000-0001-8845-7598

Antonova, D., Kunev, S. and Kostadinova, I.
Knowledge Sharing Model for Integrated Development of Products in Machine-building (Results of the Exploratory Study).
DOI: 10.5220/0010657900003064
In *Proceedings of the 13th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (IC3K 2021) - Volume 3: KMIS*, pages 126-132
ISBN: 978-989-758-533-3; ISSN: 2184-3228

performance in NPD. It proves the interdependence between the three types of knowledge sharing: of the consumers (users); the core (basic) competencies of the organization; and the suppliers' capacities.

2 RESEARCH METHOD

The goal of this research is to develop and test a **knowledge sharing model for integrated industrial product development,** using indexes for the level of teamwork, which try to clarify the three categories of shared knowledge (i.e. of the users, suppliers and core company competences) and the product presentation (i.e. time to commercialization and value to users). The main task is to elaborate a valid and reliable scale for measuring IKNPD by presenting the process and the product, i.e. cause-and-effect links of the impact of shared knowledge on the IKNPD process execution (mostly evaluated by the degree of teamworking and R&D productiveness), as well as the links between the impact of process presentation on the main strategic imperatives such as time to commercialization and value to users. The research includes hypotheses testing, empirically derived from the model:

H1. The greater the extent of shared knowledge of users, the higher the degree of teamwork and R&D productiveness.

H2. The greater the extent of shared knowledge of suppliers, the higher the degree of teamwork and R&D productiveness.

H3. The greater the extent of shared knowledge of core competences, the higher the degree of teamwork and R&D productivity.

H4. The higher the degree of teamwork and R&D productivity, the shorter the time to commercialization is.

H5. The higher the degree of teamwork and R&D productiveness, the higher the value to the user is.

2.1 Pilot Study

The design of the research process is grounded on generally accepted methods for amplification of standardized tools. The pilot study was conducted by on-line monitoring of machine-building enterprises with similar profile in May 2018. The survey questionnaire was revised to adopt some changes, suggested by academic experts and industry specialists (Frascati Manual by OECD, 2018). After it was completed, it was sent to 500 managers of large machine-building enterprises in Bulgaria, Germany, Japan and the USA.

Festo Vertrieb GmbH&Co. KG – Germany; The American Investment Fund Anchorage Capital Partners, Sydney, Australia and Advanced Technological R&D and Product sales, Yazaki Corporation, Japan provided the contacts of 500 managers, selected randomly according to their participation in machine-building enterprises. Their parameters were as product managers, with positions and geographical locations in four sectors (production of automobile components and parts; refrigeration equipment; hydraulic systems; medical and physiotherapy equipment) with codes according to the standardized industrial classification (SIC) 34, 35, 36, and 37. The answers in the initial pilot study are excluded from the full survey and the enterprises included in the pilot study are not present in the list for the large study. These steps have been undertaken in order to ensure the above-mentioned desired characteristics. The instruments used in the large-scale survey are shown in Appendix 1. The answers have been measured against five-stage Likert scales. The period of conducting the main survey was June-September 2018.

2.2 Sample

Of the total of 500 companies, 30 respondents were used for the pilot study and 205 – for the large one. 205 credible responses came from refrigeration manufacturers (22.93%); manufacture of gaming equipment (7.32%); medical and physiotherapy equipment (17.56%); production of automobile components and parts (30.12%) and hydraulic systems (16.32%). The positions of the respondents are as follows: executive directors/presidents (2.44%), senior managers (36.10%), project managers (32.68%), and others (28.29%). More than 70% of the interviewed persons have a real experience in managing multi-functional international project teams. The number of employees in the respondents' companies is: less than 500 (40%); 500-599 (15.12%); 1000-4999 (22.44%), 5000-9999 (8.78%) and over 10000 (12.20%). The companies with over 1000 employees are 43.42 % of the total.

3 METHODS FOR DATA ANALYSIS

Linear modelling of structural equations (LISREL) is applied to describe the strength of the correlations among: Shared knowledge of core/basic organization competencies; Shared knowledge of consumers (users) and supplier; Process performance; Time to commercialization; and Value for consumers (users). LISREL provides an accurate method for testing conditional models, as it can implement simulative evaluation of both conditional components and indicators in complex models. Standardized coefficients and t-values of conditional links between the elements are applied to test the hypotheses set in the study. The software package LISREL, applied for the calculations in the study is described as: Software for modelling structural equations, generated by the path of diagrams in an easy-to-use interface and syntax that is generated directly from the scheme. The calculations were performed with SSI's LISREL 8.8 licensed software for Microsoft Windows Vista.

4 RESULTS AND DISCUSSION

For the first time, an analysis of the state of product design was conducted by the Product Development and Marketing Association (PDMA), USA, through a survey among 189 American companies in 1989, followed by a second survey in 1995 with 383 respondents. The third application of the methodology was in 2003 (Barczak et al., 2009). The questionnaire developed by PDMA, as the main tool of the survey in 2003, contains 7 modules: (1) Shared knowledge of users (AD); (2) Shared knowledge of core (basic) competencies (AF, AE, AH, AN); (3) Process performance (DEVPRO); (4) Value for consumers (users) (CA, CC,CK, CM); (5) Shared Supplier Knowledge (AG,AK, AC, AJ, AA); (6) Teamwork and (7) Time to commercialisation (CIE, CIL, CIK). The encoding is done by PDMA.

Later, the PDMA tool was partially used to survey industrial companies in Sweden in 2004 (Rundquist, Chibba, 2004). A follow-up survey focusing solely on outsourced NPD was conducted in 2008 by Rundquist and Halila (Rundquist, Halila, 2010).

A parallel study on the NPD process took place in Malaysia in 2006, based on the methodological foundations of PDMA (1995) and Sweden (2004). The project coordinators are Shalabi, Omar and Rundquist (Shalabi et al., 2008). The study covers: documented process and strategies in NPD, outsourcing and organization of the process in NPD. Another independent parallel study of integrated product development that surveyed 205 US automotive engineers also reveals some interconnections with knowledge sharing with customers and suppliers (Hong et al., 2004).

In this research to test hypothetical links, a Confirmatory Factor Analysis (CFA) is done. A lot of the literature on CFAs is based on LISREL modelling. The co-variant structure of the model includes two components: a measurement model and a structural model. The measurement model establishes how hypothetical (latent) concepts are evaluated against observed variables. One of the dimensions is defined as the presence of a latent distinctive characteristic of the concept that gives grounds for a set of indicators.

Table 1: Investigated model: assessment of the parameters of the measured variables (n=205). Source: authors' elaboration, adapted from PDMA model, 2019.

Indicators	Factor loading	*t*-value	Total standard factor load	Uniqueness/ term of the error	R^2-reliability
Shared knowledge of users					
AID	1.00		0.61	0.62	0.58
A2D	1.36	8.01	0.75	0.44	0.56
A2K	1.56	9.42	0.86	0.25	0.75
A3D	1.54	9.10	0.88	0.20	0.77
Shared Supplier Knowledge					
A1G	1		0.77	0.30	0.62
A1K	1.06	11.17	0.77	0.40	0.60
A2C	0.91	9.90	0.69	0.52	0.48
A2J	1.05	10.81	0.85	0.44	0.56
A3A	1.04	10.70	0.84	0.45	0.55
Shared knowledge of core (basic) competencies					
A1F	1.00		0.81	0.35	0.65
AП	0.99	10.66	0.78	0.40	0.60
A3E	0.76	8.52	0.62	0.62	0.58
A3H	0.77	8.05	0.59	0.65	0.35
Process performance					
Team-work	0.90		0.67	0.24	0.67
DEVPRO	1.00	15.78	0.66	0.23	0.67
Time to commercialisation					
C1E	1.00		0.95	0.09	0.91
C1L	0.68	10.25	0.63	0.60	0.40
C1K	0.90	15.34	0.84	0.30	0.70
Value for consumers (users)					
C2A	1.00		0.74	0.46	0.54
C2C	1.30	11.86	0.85	0.20	0.72
C2K	1.14	11.64	0.83	0.31	0.69
C2M	1.30	11.53	0.82	0.32	0.68

Table 2: Levels of reliability, correlation, and discriminant validity of the components. Source: authors' elaboration, adapted from PDMA model, 2019.

	1	2	3	4	5	6
1. Shared knowledge of users	0.86					
2. Shared Supplier Knowledge	0.21					
3. Shared knowledge of basic competencies	347.47 0.52	0.82 0.44	0.85			
4. Process performance	163.28 0.68	171.15 0.41	0.64	0.90		
5. Time to commercialisation	192.78 0.47	371.88 0.28	135.00 0.44	0.69	0.88	
6. Value for consumers (users)	252.74 0.54	282.51 0.33	157.79 0.51	171.61 0.80	0.55	0.91
7. Mean	3.92	3.10	3.79	3.52	3.57	3.77
SD	0.08	0.80	0.64	0.73	0.97	0.92

Based on the assessment of the compliance of a one-dimensional model for each variable, iterative modifications were undertaken. Modifications are made to improve the model's compliance, as well as to deliver parameters that are of real importance and significance.

The greater the loading of the factor or the coefficient, compared to its standard error and displayed by the corresponding t-values, the stronger the proof that the measured variables or factors confirm the basic ideas. Generally, if these t-values are greater than 2 or 2.576, they are considered significant at a level of 0.05 to 0.01. In Table 1 above, it can be seen that all t-values exceed 2.576.

Consequently, all indicators are significantly related to their defined concepts. Factor loads are over 0.5, which means that all indicators have good values compared to their thresholds. The R2 values refer to the reliability of the indicators. The values of R2 over 0.5 mean that less than 50% variation will be a variation error, which provides evidence of acceptable reliability.

Most of the R2 values are above 0.5. The values of R2 and t-values provide evidence of convergence validity. Table 2 shows a correlation matrix, as well as the internal consistency coefficients Cronbach Alpha. The reliability of all metrics is over 0.80. According to similar calculations (Nunnally, 1978), reliability over 0.70 is considered satisfactory. Discriminant validity is reached when the difference between a restricted and an unlimited model is significant (x2 of df, x2=1). As shown in Table 2 above Chi-square values are all at a significant level.

With these results, the testing of the proposed models was done using LISREL. Analysis of structural equations was used to test these models. The results are shown in Table 1. For a complete assessment of the conformity data-model x2, the Number of Degrees of Freedom, Compliance Index (CFI), and Bonnett Non-Shared Compliance Index (NNFI) were used. With respect to NNFI and CFI, values between 0.80 and 0.89 represent a good match data-model, while values of 0.90 or higher represent a very good match. This shows a range of indices from 0.0 (no match) to 1 (full match). The RMSEA (square estimate value error) of less than 0.05 is a close match data-model. As shown in Table 2, the structural model outputs the covariate matrix very well (x2=298.71; df=201; NNFI=0.96; CFI=0.96, RMSEA=0.049). Because the structural model has a reasonably matching model-data pattern, a study over the path of the coefficients might be done. Figure 1 bellow shows the test results of the proposed hypothesises.

H1 – H3 provide that the shared knowledge of users, suppliers and core competences will be directly connected to the results from the presentation of the process. As seen in Fig. 1, the maximum probability estimations for the path from shared knowledge of users, suppliers and core competences are significant and positive (standard coefficients of 0.48, 0.17 and 0.35, with t-values of 5.71, 2.58 and 3.79, respectively). This shows that teams, operating with high levels of shared knowledge of users, suppliers and core competences demonstrate much better results in presenting the process than those with low levels of shared knowledge.

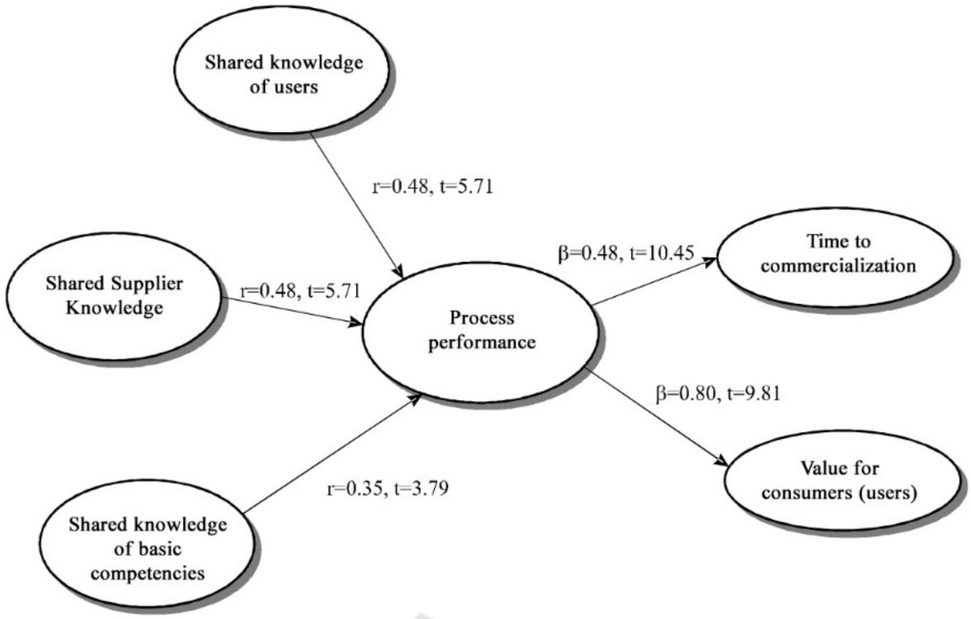

Figure 1: Evaluation of the elaborated model by analysis of structural equations.

H4 and H5 provide that the degree of presentation of IKNPD process (i.e. team work and R&D productivity) will be connected to the results from the presentation of the product (i.e. the time to commercialisation and value for the user). In Fig. 1 it is clearly seen that the maximum probability estimations for the path from the presentation of the process to the time to commercialisation and value for the user are significant and positive (standard coefficients of 0.69 and 0.80, with t-values of 10.45 and 9.81, respectively). This shows that the higher levels of team work and R&D productivity lead to shorter time to commercialisation and provide higher value for the users.

5 CONCLUSIONS

First of all, one contribution of this study is the amplification of a reliable tool for measuring the level of knowledge sharing in the field of IKNPD, which can be used to assist future studies. The results obtained from the survey of managers in machine-building prove that knowledge generation is a pre-requisite for creating successful innovation projects not only in the Hi Tech Industries, as it is commonly believed, but also in traditional ones. Identifying streams of shared knowledge allows researchers to implement the approach of knowledge management in applied fields such as NPD, e-commerce or marketing of industrial products.

Secondly, as it was assumed, the three components of shared knowledge (users, suppliers and core competences) are positively related to the presentation of NPD process. The influence of shared knowledge is reviewed in another context as well – as characterisation of research teams, defining success in outsourcing and building capacity for NPD. This study shows how the specific components of knowledge sharing support the IKNPD process (i.e. team work and R&D productivity) and what the strategic results (i.e. time to commercialisation and value for the user) are. The study confirms the fact that when teams act in an external environment that fosters knowledge sharing between users, suppliers and core company competences, the presentation of the process (team work and R&D productiveness) connects the effect of knowledge sharing with strategic directions - time to commercialisation and value for the users. The results from the study propose that knowledge must be shared reasonably within the members of the teams in their efforts to design products or processes. Managers should concentrate on methods for improving team work and R&D productiveness through intensifying the knowledge sharing among the team members.

Thirdly, if time to commercialisation and value for the users represent strategic directions, knowledge sharing is an important driving force. It can also be a drive for other strategic imperatives like production opportunity and thus enhance the general organisational competitiveness.

Last but not least, in order to introduce IKNPD efficiently, integration must take place at conceptual level first because product development is a job, related to intensive use of knowledge. The study conducted provides support for the five hypotheses and better understanding of the elements in the foundation of shared knowledge in IKNPD, as well as proofs of claims not tested before with regard to the elements of integrated knowledge.

REFERENCES

Antonova, D. et al. (2018). Concept of Online Distance Learning System on Sustainable Development in the Cross-border Region. *TEM Journal, 7(4)*, 915-923.

Antonova, D., Stoycheva, B. (2018). Approved model of factors, influencing the management process in developing new products. In *The 6th International Conference Innovation Management, Entrepreneurship and Sustainability (IMES 2018), Czech Republic*, 38-54.

Barczak G., Griffin A., Kahn K. (2009) Perspective: Trends and drivers of success in NPDpractices: results of the 2003 PDMA best practices study, *The journal of product innovation management, 26*, 3 – 23. DOI:10.1111/j.1540-5885.2009.00331.x

Griffin, Ab. (1997). PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices. *Journal of Product Innovation Management, 14(6),* 429-458. DOI 10.1016/S0737-6782(97)00061-1.

Hong, P., Doll, W., Nahm, Ab., Li, X. (2004). Knowledge sharing in integrated product development. *European Journal of Innovation Management, 7.* 102-112. DOI 10.1108/14601060410534393.

Iliev, S., Gunev, D., Kadirova, S., Nenov, T., Ivanov, I., Kunev, S. (2018). Improving Practical Experience of Students in Pre-production and Production Stages of New Products. DOI 10.1109/SIITME.2018.8599282. In *2018 IEEE 24th International Symposium for Design and Technology in Electronic Packaging (SIITME)*, Oct. 25–28, Iasi, Romania, IEEE, 2018.

Kostadinova, I. et al. (2019). Integration of principles of responsible management education in regard of social resposibility's learning needs. *Annals of „Eftimie Murgu" University Reşiţa. Fascicle II. Economic Studies, XXVI edition*, 132-142.

Kunev, S. et al. (2012). Algorithm for factor determination of innovation activeness of machine-building SMEs (the case of Bulgaria, example of Ruse region). In *2nd International Conference on Logistics and Maritime Systems, University of Bremen, Germany*, Imprint: University of Bremen, Faculty 7: Business Studies& Economics, Chair of Logistics, 2012, 293-302

Kunev, S. (2010). Using Case Study in Entrepreneurship and Innovation Education: Methodological Aspects. *Journal of Entrepreneurship and Innovation, year II, 2*, 45-56.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). New York: McGraw-Hill, 1978.

Ostravik, F. (2004). Towards a communicative theory of diverse innovation systems. *Diversity of Knowledge Economy and Society, Series editors: E. Karayaniss & A. Kaloudis, Cheltenham, U.K.*, 117-140.

Rundquist, J., Chibba, A. (2004). The use of processes and methods in NPD-A survey of Swedish industry. *International Journal of Innovation and Technology Management, 21,* 37-54. DOI 10.1142/S02198770040 00076.

Rundquist, J., Halila, F. (2010). Outsourcing of NPD activities: A best practice approach. *European Journal of Innovation Management, 13*, 5-23. DOI 10.1108/ 14601061011013203.

Ruskova. S., Ruseva, I. (2018). Empirical study on the impact of the conflicts on the motivation of the employees. *Annals of "Eftimie Murgu" University Resita, XXV*, 206-215.

Ruskova, S. (2012). Research of the Motivational Factors Affecting the Different Categories of Consumers according to the Rogers' Model. *Entrepreneurship and Innovation, 3,* 51-74, ISSN 1314-0175

Shalabi, Am., Omar, M., Rundquist, J. (2008). Processes and strategies of NPD: A survey of Malaysian Industry. *International Journal of Manufacturing Science and Technology, 10*, 91-95.

Shah N., Tsai, C., Marinov, M., Cooper, J., Vitliemov, P., at al. (2009). Ontological On-line Analytical Processing for Integrating Energy Sensor Data. *IETE Technical Review, 26*, 375-387.

Stoycheva, B., Antonova, D. (2016). Improving Management Functions in Developing New Products in Medium-sized and Large Enterprises (a Comparative Study of Bulgarian and American Processing Industry). In Kotzab H., Pannek Jürgen, Thoben Klaus-Dieter (eds.). *Dynamics in Logistics.* Springer International Publishing Sw. Berlin-Heidelberg, Germany, LDIC 2014, 667-674.

Stoycheva, B., Antonova, D. (2018). Investigating Factor Interactions in Formalising the Process of Developing New Products. *Serbian Journal of Management, 1(13)*, 173-184.

Todorova, M., Ruskova, S. et al. (2011) Method for Studying the Students Needs of Training in Entrepreneurship. *Scientific Bulletin of Politehnica University of Timisoara, 5*, 5-14, ISSN 1224-6050.

Vitliemov P, Ivanov, S. (2001). Parametric Assembly Design. *Advances in Manufacturing Technology, XV*, Cardiff, UK.

Zlatarov P., Ivanova G. et al. (2018). Adaptive Software System for Optimization of the Admission and Management Process for Doctoral Students, https://doi.org/-10.1007/978-3-030-00184-1_30. In Silhavy R., Silhavy P., Prokopova Z. (eds.) *Intelligent Systems in Cybernetics and Automation Control Theory. CoMeSySo 2018. Advances in Intelligent Systems and Computing.* Springer, 2018, (860), 323-332.

APPENDIX

Indexes included in the basic study (end indexes)

Indexes		Measured indexes	Mean	SD
		This IKNPD team shares knowledge of		
Shared knowledge of users	A1D	Customer's requirements	4.18	0.84
	A2D	Which characteristics are most valued by the target customers	3.93	0.94
	A2K	Current needs of the customer	3.93	0.94
	A3D	What does our customer want	4.02	0.91
Shared Supplier Knowledge	A1G	What are the capacities of our suppliers for implementing the process	3.11	0.92
	A1K	Capacities of our supplier to meet the requirements for target expenses	3.03	0.99
	A2C	Supplier capacities for design	2.98	0.95
	A2J	Capacities of our supplier to meet the requirements about the time factor	3.29	1.01
Shared knowledge of basic competencies	A3A	Capacities of our supplier to meet the requirements about quality	3.17	1.02
	A1F	Capacities of our engineering staff	3.95	0.80
	A1I	Strengths of the capacities of engineering staff	3.91	0.82
	A3E	Strengths of our production facilities	3.73	0.84
	A3H	Capacity of the technologies used in the process	3.61	0.84
		This R&D team		
Team work	C1C	Good teamwork	3.82	0.92
	C1H	Activities are well-coordinated	3.51	0.98
	C1M	Solutions are successfully implemented	3.57	0.95
	C1N	Communication is carried out smoothly	3.53	0.97
NPD activity	C1D	Productive	3.97	0.85
	C1G	Uses financial resources rationally	3.58	0.90
	C1J	Uses all resources for R&D rationally	3.33	0.98
	C1L	Uses time for engineering work efficiently	3.32	0.95
Market launch time	C1B	Keeps the deadline for launching on the market	3.69	1.18
	C1E	Develops the product on time	3.60	1.11
	C1I	Reduces the product development time	3.29	1.13
Value for the customer	C2A	The product is of high quality	4.00	0.94
	C2C	The product surpasses the customer's expectations	3.57	1.06
	C2K	This product is of high value for the customer	3.91	0.95
	A3D	What does our customer want	4.02	0.91
	C2M	This product is successful in the market	3.79	1.10