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The Optimization of Automobile Part Product Development Using Integrated Product Development (IPD)

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ABSTRACT

This paper studies a new integrated product development (IPD) process at an automobile parts company. The process includes benchmarking and offers four optimization strategies for the new product development process: (1) re-structuring the new product development organization astraddle department teams, (2) reshaping the new product development and selection process already at the planning and conceptual design stages, (3) optimizing the design review process at the engineering stage, and (4) establishing a product development team with large project manager responsibilities in the industrialization stage so as to give full play to the guiding role of expert resources. This paper can help enhance the competitiveness of domestic auto parts enterprises compared to leading foreign auto parts enterprises.

KEYWORDS

Automobile Parts, Integrated Product Development, Optimization Strategy, Product Development Process

INTRODUCTION

With the rapid development of the automobile industry, the automobile parts industry has become an important foundation to support the sustainable development of the automobile industry (Tzokas et al., 2004). With the globalization of the economic market, the position of the auto parts industry in the auto industry system is constantly improving (Gerwin & Barrowman, 2002). At present, China's automobile industry has been ranked first in the world for nine consecutive years, and its sales volume has accounted for more than 30% of the world share (Smith & Morrow, 1999). The increase in vehicle sales has brought about a huge demand for accessory parts, but the market share of automobile parts in China is not ideal, which is mainly due to the fact that China pays attention to the development of whole vehicles and ignores the development of components and related accessory industries (Schilling & Hill, 1998). In order to enhance the competitiveness of China's auto parts industry, it is an urgent problem to strengthen the R&D of auto parts products (Koufteros et al., 2002).

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At present, a lot of research and successful practical experience have been carried out from the perspectives of management methods and development processes for improving the research process of automobile parts in China (March-Chorda et al., 2002). Some researchers summarized the whole process of product development of existing components, combined with the management model of automobile development, described the core work content and technical requirements of the product development stage, and divided the product development stage into market strategy, product planning, conceptual design, product engineering, development verification, and formal production processes (Ye et al., 2008). By analyzing the actual product development process of Jiefang Company, some researchers, from the point of view of the fact that the actual business process is not in line with reality and the process is cumbersome and unsmooth, incorporate excellent practical theory, formulate the optimization scheme of the product development process, and improve the product management system of China's automobile enterprises (Gerwin & Barrowman, 2002). Some researchers put forward a new product development process under the guidance of enterprise strategy, which transforms product ideas into the final marketing plan through a series of development, prediction, and control procedures and takes the process of successfully transforming new product ideas into products on the market as the main focus of work (Bullinger et al., 2000). Some researchers believe that the new product development process is composed of relatively independent and overlapping stages, which run through the product development process from conceptual design to product structure design, product marketing to product delivery to customers. Facing the situation of increasingly fierce market competition, automobile core components have always occupied a pivotal position in the automobile industry system (Sommer et al., 2014). In order to continue developing successfully, automobile enterprises must optimize the development process of component products (Wind & Mahajan, 1988). Taking Auto Parts Company A as the research object, this paper sorts out the concept and model of the component product development process, analyzes the problems existing in the component product development process of Auto Parts Company A based on the integrated product development (IPD) theory, and puts forward the optimization strategy of the component product development process, which provides theoretical data support for the optimization of the component product development process of auto enterprises (Zahay et al., 2004).

CURRENT SITUATION AND PROBLEMS OF PRODUCT DEVELOPMENT PROCESS OF AUTOMOBILE PARTS

Research Object

Auto Parts Company A is a leading research and development (R&D) institution for automobile engines in China first established in 2013 (Ottosson, 2002). The company adopts a functional organizational structure, with three departments and nine professional departments (Figure 1). It is responsible for R&D projects, such as engine and automatic and manual transmissions, and provides support for the R&D of the whole vehicle. The company has also entered into strategic cooperation with Volvo cars to jointly develop a 1.5-liter supercharged direct injection gasoline engine and an efficient seven-speed dual-clutch transmission (7DCT) powershift.

The company adheres to the concept of forward design and R&D, has mature design, simulation, calibration, and test capabilities, and at the same time has the leading software and hardware resources in the industry, which can realize independent R&D of high-quality power products (Song et al., 1996). The company's main advantages (Table 1) are that it has mature capabilities in engine combustion development, mechanical function development, and durability development, as well as, for example, engine performance simulation, cooling and lubrication simulation analysis, combustion process simulation, and noise, vibration, and harshness (NVH) performance simulation. It has been approved by the CNAS National Laboratory and can meet the test requirements for engine, transmission, NVH, and emissions. At the same time, the developed 1.8T and 2.0T direct injection engine products have

Figure 1. Functional organizational structure of the company

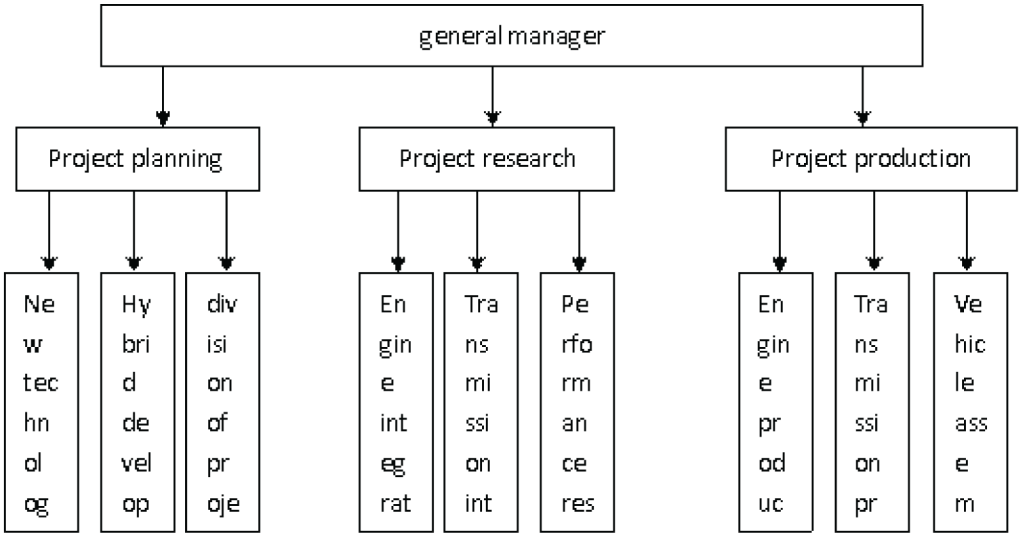


Table 1. Main advantages of the company

Product Development Stage	Main Advantages
Design	With mature engine combustion development, mechanical function development, and durable development capabilities.
Simulation analysis	It has mature capabilities of engine performance simulation, cooling and lubrication simulation, combustion process simulation, multi-body dynamics simulation, NVH performance simulation, etc.
Calibration aspect	It has independent calibration of engine and automatic transmission.
Experimental aspect	It has a first-class powertrain test center, which has been approved by CNAS National Laboratory, and can complete the engine, transmission, NVH, emission, and other test requirements.

excellent fuel economy and power, which promotes the development of world-class power products in the 3.0 era.

With the company's increased investment in R&D and the increase of new product development projects (Figure 2), problems such as the lack of refined and systematic management in the new product development process have been exposed, and it is inevitable to optimize and upgrade the new product development process.

Current Situation of New Product Development Process

The organizational structure of the company's new product development adopts the project-oriented organizational structure (Figure 3). The project team sets up a leadership team and, according to their functions and duties, basic resource groups such as human resources, finance, legal affairs, and other professional departments are also set up such as project management, planning and sales, R&D, logistics and transportation, purchasing and storage, and good quality control.

Company A adopts the NPDS-PT new component product development process. By summing up the company's new product development experience and lessons, a total power cost

Figure 2. R&D investment of the company

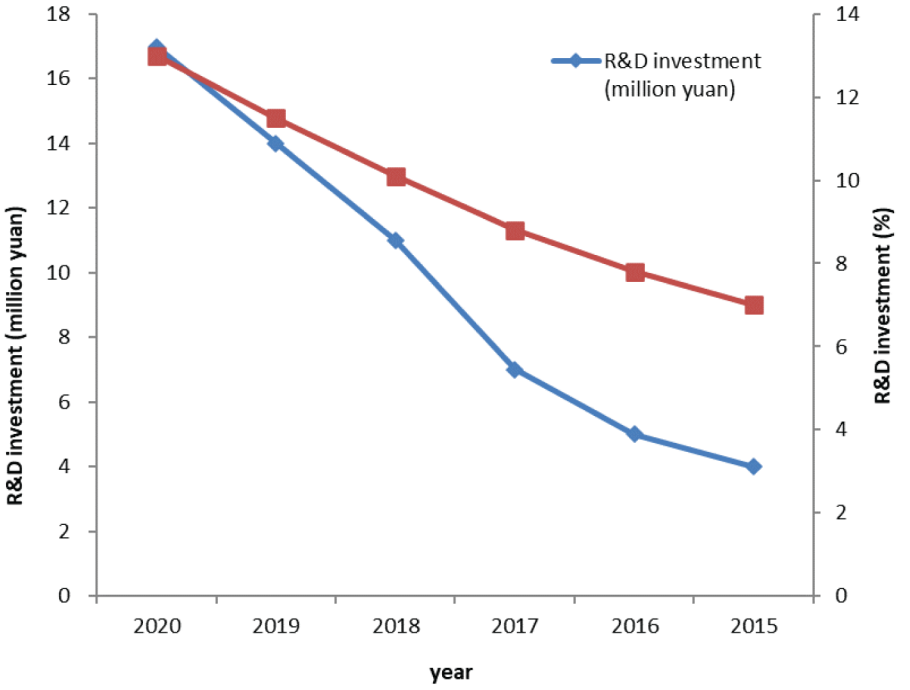
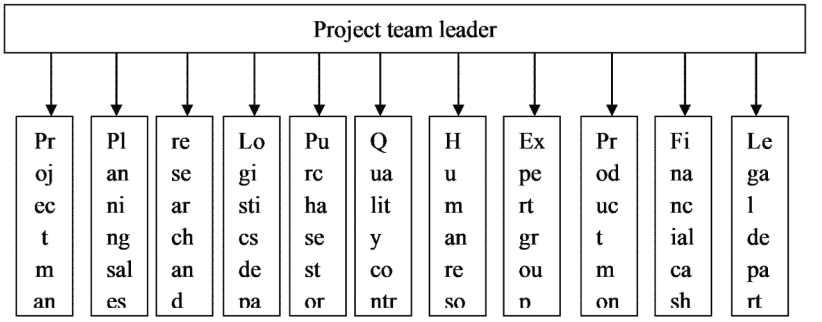


Figure 3. Project-based organizational structure



development system is established based on the whole vehicle development process, including the whole process from project establishment to vehicle mass production. The NPDS-PT product development process (Figure 4) refers to the development process and product delivery of new components, aiming at developing products that satisfy customers with the least resources and the shortest time. In this paper, the company's auto parts product development process is divided into a strategic planning stage, a conceptual design stage, an engineering stage, and an industrial development stage (Table 2).

Figure 4. The NPDS-PT product development process

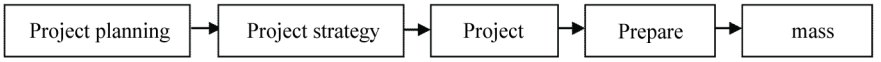


Table 2. Contents of automobile parts product development process completed at different stages

Development Phase	Main Content Completed
Strategic planning stage	Make strategic preparations for the approval of product projects, carry out market research and product positioning research, and determine the sales volume, cost, product technical characteristics, development cycle, profitability and other conditions of products. Whether the decision at this stage is reasonable or not will directly determine the success of the project and the investment benefit.
Conceptual design stage	Complete the development of product project design scheme, and refine the market, engineering, manufacturing and quality. At this stage, we mainly solve the problems of product quality, cost and industrialization, and avoid defects by optimizing the design.
Engineering stage	Complete product detailed design and early verification through product engineering, manufacturing engineering, supplier development, quality and other modules, release final engineering data and drawings, and complete the manufacturing and verification of engineering prototype.
Industrialization stage	Promote the maturity of manufacturing quality of components and whole machines, realize mass manufacturing of products, develop mass production tooling and molds, and verify whether products meet product technical specifications.

Existing Problems in the Different Stages of the Development Process

With the rapid development of enterprises, Company A found that in the process of component product development, there was a mismatch between business processes and organizational capabilities, and organizational hierarchy hindered innovation (Hong et al., 2011). At present, the trend of the company's new product development is large-scale, more detailed division of labor and more professionalism, which leads to more detailed division of functions and fewer opportunities for direct communication, which also leads to confusion of management channels (Tidd & Bodley, 2002). At present, the project-based organizational structure, both project team members and functional organizations, has poor cooperation, a low resource utilization rate, and an extremely low sharing of knowledge and skills (Broberg, 1997).

In the planning stage, customer-centeredness is the consensus of enterprise management, and accurately grasping the market is the most critical. The company's market demand management lacks structured demand management, perfect product planning, and technology platform planning (Calantone & Di Benedetto, 1988). In the process of product development, the company is currently dominated by the positioning of competing products in the market, which leads to the fact that the development of new products is centered on product competitiveness while the demand for products is neglected (Parker, 2000). Platform-based development strategies can improve the quality, cost, and progress of new product development projects (Rauniar et al., 2008). The final embodiment of technology is the products delivered to customers. Products are made up of different components. These components are commonly called general component modules among different products. By forming the common parts among different products into product platforms, the core technologies and key technologies determine the main functions and performances of product platforms and related products. The development of platforms puts forward higher requirements for product and technology planning, so sharing common modules among different products must be done in advance. Table 3 shows the influence of the

Table 3. Influence of the company's lack of systematic new product and technology platform planning on product development

What the Company Lacks	Impact on Product Development
Lack of correspondence between products and technologies	In the planning of products and technologies, the identification of technologies is very important. Only by mastering the core technologies and some key technologies can we build our own core competitiveness. Without the screening and planning of technologies, we can't lead the development of product differences and our own core competitiveness.
Lack of unified management process and team	In the process of product development, the development of technology only depends on the new technology development department to develop and manage the market frontier technology and competitive product information, and there is a lack of professional technical developers to develop the platform.
Lack of forward-looking development of products and technologies	Without the common needs of future customers, any advanced technology must solve customers' problems, and the attention to customers' needs should be long-term. If technology is separated from customers' needs, it will naturally not be able to promote the development of products. No matter technology pre-research or product and platform development, it should be guided by market customers' needs.

company's lack of systematic new product and technology platform planning on product development in the engineering development stage (Moffat, 1998).

Lacking a reasonable selection process in the conceptual design stage, in the selection stage the decision-making level is too low and, according to the functional organization, plans and decisions are submitted from bottom to top, which leads to the waste of project resources and inefficient operation (Brunetti & Golob, 2000). At the same time, too many institutional decisions lead to uneven quality of plan decisions, and managers are not professional enough, so it is impossible to reach a reasonable selection (Khaleeq uz Zaman et al., 2017). At present, the company's demand lacks timely response to market demand, and many decisions are not based on the market but on the management and decision-making bodies (Moffat, 1998). Due to the lack of systematic and scientific demand research in the selection stage and the lack of quantitative requirements for the quality and performance of specific products, the product generalization is poor, the product development is wasted, and the problems of redevelopment and a high rejection rate are brought about (Mulebeke & Zheng, 2006).

The development process in the engineering stage lacks structure. According to the company's current NPDS-PT new product development process, the engineering process is to provide 2D drawings and 3D digital models of Version A at the data review Node 1 according to the project progress, and the updated 2D drawings and 3D digital models of Version A at the data review Node 2 (Monplaisir, 1999). The final data review node provides the final version of 2D drawings and 3D digital models and establishes a trial-production and fitting module (Xie et al., 2001). The trial-production and fitting module conducts process analysis, formulates a tool list, processes samples, assembles and manufactures them, and formulates a tooling design scheme after technical communication with customers (Srinivasan et al., 1997). However, at present, due to the lack of internal coordination, the progress of the previous process is delayed, which directly affects the development of the next step, the development cycle that can be shortened is not optimized, and the design lacks commitment, which affects the subsequent development work and the overall project progress (Levandowski et al., 2014).

COMPONENT PRODUCT DEVELOPMENT PROCESS OPTIMIZATION

Product Development Organization Restructuring

The cross-departmental team is the link between professional departments and cross-process departments, and the key to the successful operation of the IPD system. The construction of cross-departmental teams belongs to capacity building and ultimately serves the business and market

(Demoly et al., 2010). According to existing practice, in the IPD system, the most important inter-departmental teams are the decision-making team, the planning team, and the development team, and other teams are extensions of these three teams.

In the process of new component product development, the company's senior management and product line decision-making level are needed. High-level decision-making affects the efficiency and results of new product development, so a good product development process should establish an inter-departmental decision-making team and decision-making process, thus providing support for the company's decision-making. At the same time, the middle and senior management levels of the IPD system undertake business decisions and collective decisions in new product development. If the senior management also has the corresponding technical evaluation ability, it can also play a full role in the technical evaluation, but it is necessary to have a clear division of responsibilities, which helps different roles to perform their duties. Table 4 shows the changes of functional departments' responsibilities under the IPD mode. By constructing a flexible strong matrix architecture to adapt to the strategy of business upgrading, the efficiency of new product development can be improved. At the same time, when a certain member of the project participates in several projects, when encountering resource conflicts, according to the needs of the company's business and taking the interests of the company and customers as the starting point, the priority of work should be reasonably arranged.

Reshaping the Selection Process of New Product Development

Using Huawei's IPD system as a reference, the four most important inter-departmental teams, namely, the decision-making of the integrated portfolio management team, the business staff of the product development team, the staff of the technical development team, and the development and execution of the product development team, support the implementation of the IPD process. A component company needs a professional business staff team to make a business plan, product signpost planning, and project task book; a professional technical staff team to make a technical strategy, technical signpost planning, and project task book; and a professional new product development team to carry out project development to ensure the success of the product market. The candidates for these professional teams must be highly matched with elite talents according to the requirements of their posts. According to the actual situation of a component company, they must be professionals who know both technology and management and are proficient in the new product development process. These professional teams can provide scientific decision-making for senior management and promote the efficient development of various planning and execution tasks.

The requirement realization and verification stage is mainly realized through the product and technology development process, which is parallel to the "double V" model of business plan realization.

Table 4. Changes of functional departments' responsibilities under integrated product development mode

Role of Functional Departments	Work Content Changes
Core work	From the traditional one to the one that is completely divided by vertical functional departments, in case of resource conflict, it is inclined to the horizontal team according to the responsibilities of the organizational structure to ensure the progress of the horizontal work, and the work evaluation is also measured by the horizontal team and the cross-departmental product development team.
Orientation of functional departments	From the previous role of assisting and cooperating with new product development, it changed into a part of an inter-departmental team and cooperated to complete the development of new products.
Operating duty	Work includes research and development of new products, own work of listed products and internal construction in this field. In case of conflict, resources will be arranged according to the priority of market demand.

In the conceptual stage of new product development, after the requirements are formed, the product and system engineers decompose the implementation scheme of the requirements to form the system requirements, then freeze the design to form the baseline design review 1, and then complete the implementation and verification stages from design review 2 to design review 4 according to the technological development process. At the same time, to ensure the quality of demand, we set up a demand management team and a demand analysis team at different levels according to Huawei's practice, set up cross-departmental teams at the company level and product line level to support the process operation, and incorporate related work into functional departments as part of the department's work. The demand management team at the company level is consistent with the company's business objectives and conducts regular collection activities through the market and other departments. The demand management team of the product line is mainly responsible for the implementation of product line demand management processes, methods, tools, release and management monitoring of product line demand, and the skills of demand managers.

Platform development is to endow products with sufficient technical preparation to support the development of new products, which can improve the quality, cost, and development progress of new products at the same time. At present, Component Company A has separated product development from technology development and also has a professional department of technology management, but it lacks a mature platform development process and an inter-departmental technical management team. Huawei's platform development strategy integrates technology and platform planning into one process and, in the actual operation process, it is led by the R&D field representatives in the technical management team or product planning team, which can be seen as functional field planning. One of the core ideas of IPD is platform development, which advocates identifying and breaking through the core technologies, key technologies, and common parts before new product development so as to ensure the cycle of new product development and product quality. At the same time, it should be shared between the same product line and different product lines as much as possible and even be applied to products in a forward-looking way.

Component Company A should learn from Huawei's application practice and set up a professional technical management team, incorporate expert resources and a chief engineer responsibility system into the top-level design of technical management, establish an end-to-end TPP/TPD management process, and define the review template, process, and professional decision-making system of each step and stage. For example, in the forward-looking design of products based on the accumulation of technology platforms and the demand for market collection, the chief engineers and experts who need to participate in the evaluation and decision-making should check the quality of platform development to ensure the professionalism of product iterative development.

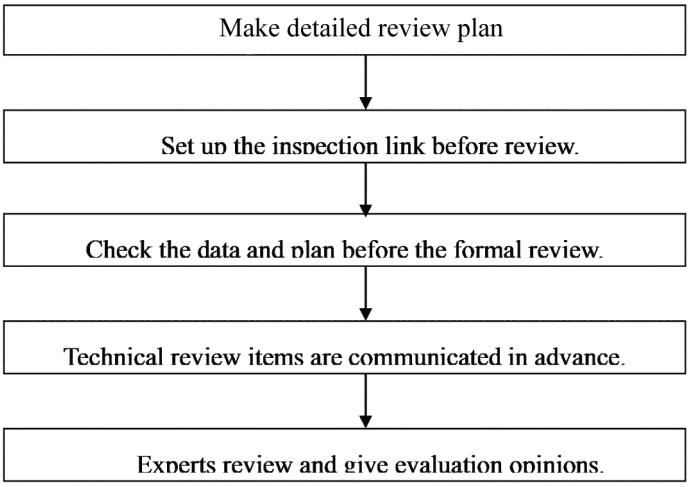
Implementing Structured Process Optimization

Optimizing the design review process, the key points of technology review should be grasped first, then gradually introduced into the process of new product development, and the departmental walls that are easy to appear should be made thinner. At the same time, two review nodes should not exceed three months, and design review nodes should be added. For complex and high-tech products, it is suggested to set up more design review nodes, which can only be submitted for business decision review after passing the DR review. Company A's design review nodes include concept endorsement, interface definition, interface confirmation, design freezing, development and verification completion, and task handover to the production team.

To improve the efficiency and quality of the review, ensure the smooth progress of the project, and avoid changing the design review meeting into a solution discussion meeting by optimizing the process. The review meeting must have a conclusion and ensure the feasibility and correctness of the scheme. Figure 5 shows the review workflow.

The product concept realization stage plays a decisive role in the accuracy of the work in the engineering stage, and the acceptance and achievement of each link directly affects the progress,

Figure 5. Review workflow



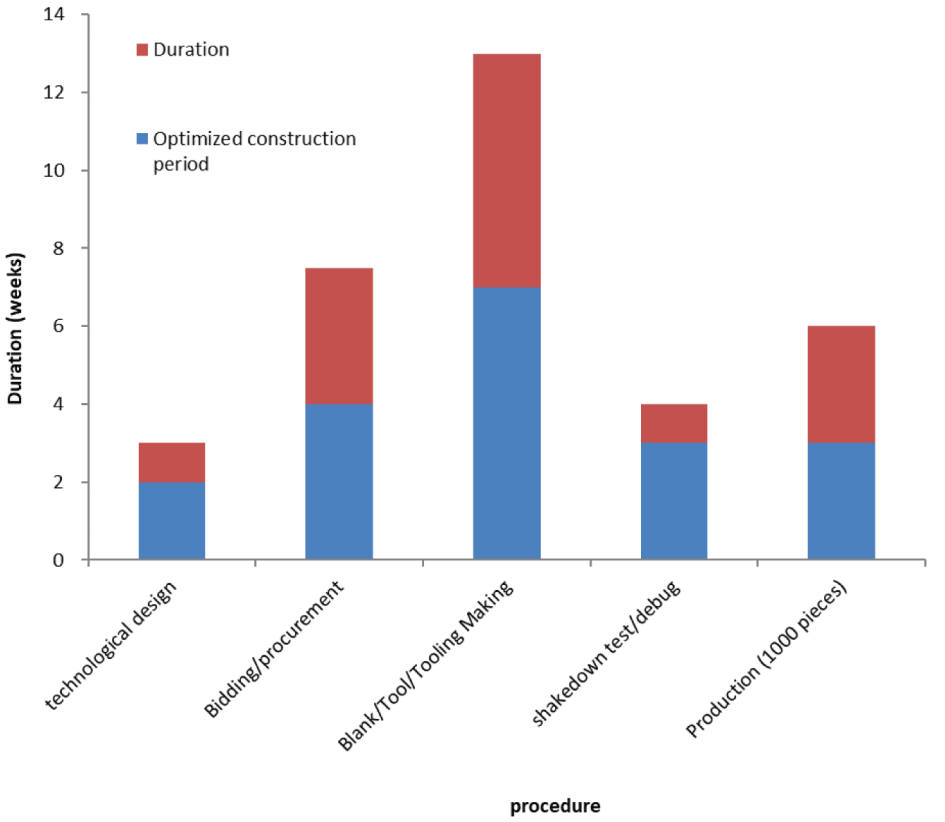
cost, and quality of the product. During the product conceptual design, the 2D drawings and 3D digital models of the engine development platform should be made simultaneously, the process analysis and process list of the trial-production and fitting module should be given, and the tooling for sample processing and prototype assembly should be designed. Figure 6 shows the optimized product development cycle. At present, the NPDS-PT new product development body of Company A is similar to some R&D evaluation models. A company draws lessons from the review content of existing achievements in the R&D field, dynamically controls the status of the project, ensures the normal progress of the project and business objectives, and everything goes smoothly.

Improving the Management Mechanism of New Product Development Projects

A professional product development management team should be established to be directly responsible for the development of new products and have absolute leadership over the resource management of the project. For the company, the appointment of experienced, competent project managers or chief engineers as the general manager ensures the quality of new product development and improves the efficiency of cross-departmental team management. In the IPD system, a complete cross-departmental team should be set up, including the product development management team composed of team managers, finance, marketing, quality, procurement, after-sales, R&D, and manufacturing. At the same time, the core members of the product development management team should be relatively fixed and responsible for new product development projects related to multiple projects simultaneously, and their correlation is reflected in the same market for products or based on the same platform and technology, which helps solve the shortcomings of traditional project-based organization managers who do not have continuity of application and cannot realize long-term attention to product performance and continuous upgrading of products.

As innovation and R&D are regarded as talents and technicians, so these activities are unmanageable and difficult to structure. A company practice test shows that, in the conceptual stage, one should give full play to the collective wisdom of experts, improve the success rate of new product development, and make up for the lack of team ability, especially in the matrix structure and IPD mode. Flexible cross-functional and cross-team development requires a more scientific mechanism for expert resources to fit in with the new product development process.

Figure 6. Optimized product development process cycle



CONCLUSION

In the face of increasingly fierce market competition, automobile core components have an important influence on the automobile industry. Enterprises should persist in optimizing the product development process of components, establish a product development process that quickly responds to the market and grasps the customer's needs, and develop competitive new component products. Taking Auto Parts Company A as the research object, this paper sorts out the new parts product development process, analyzes the problems existing in the company's new product development process based on IPD theory, and puts forward the optimization strategy of the company's new product development process, which provides theoretical data support for the optimization of the auto parts product development process in auto enterprises. The main research results are:

(1) The management status and problems of the company's new product development process are analyzed and expounded, and the problems existing in the whole planning and conceptual design stage, engineering stage, and industrialization stage of the new product development process are comprehensively analyzed. In the whole process, the mismatch between business processes and organizational capabilities and the lack of coordination among departments lead to the company's inability to concentrate superior resources for new product development. In the project planning stage, the lack of a complete definition of demand management and systematic analysis of market demand leads to the inability of new product development projects to respond to the market in time. In the conceptual stage, there are too many decision-making institutions and levels, and the

unscientific decision-making in the early stage leads to poor generalization of components and a high rejection rate. The lack of good continuity between the engineering stage and the product development steps affects project progress and product quality.

(2) Drawing lessons from the core idea of an IPD system and the existing successful practices, we will build optimization measures and strategies for the problems existing in the company's new product development process, change the organizational structure from a project system to a matrix system, and match the organization and process; in the planning and conceptual design stage, reshape the selection process for new product development, establish a systematic demand management process, and optimize the general development strategy; and in the industrialization stage, improve the project management mechanism for new product development and, at the same time, set up an inter-departmental management team with a project manager responsibility system and give full play to the guiding role of expert resources.

REFERENCES

Broberg, O. (1997). Integrating ergonomics into the product development process. *International Journal of Industrial Ergonomics*, *19*(4), 317–327. doi:10.1016/S0169-8141(96)00041-8

Brunetti, G., & Golob, B. (2000). A feature-based approach towards an integrated product model including conceptual design information. *Computer Aided Design*, *32*(14), 877–887. doi:10.1016/S0010-4485(00)00076-2

Bullinger, H. J., Warschat, J., & Fischer, D. (2000). Rapid product development: An overview. *Computers in Industry*, *42*(2-3), 99–108. doi:10.1016/S0166-3615(99)00064-0

Calantone, R. J., & Di Benedetto, C. A. (1988). An integrative model of the new product development process: An empirical validation. *Journal of Product Innovation Management*, *5*(3), 201–215. doi:10.1111/1540-5885.530201

Demoly, F., Monticolo, D., Eynard, B., Rivest, L., & Gomes, S. (2010). Multiple viewpoint modelling framework enabling integrated product-process design. *International Journal on Interactive Design and Manufacturing*, *4*(4), 269–280. doi:10.1007/s12008-010-0107-3

Gerwin, D., & Barrowman, N. J. (2002). An evaluation of research on integrated product development. *Management Science*, *48*(7), 938–953. doi:10.1287/mnsc.48.7.938.2818

Hong, P., Doll, W. J., Revilla, E., & Nahm, A. Y. (2011). Knowledge sharing and strategic fit in integrated product development projects: An empirical study. *International Journal of Production Economics*, *132*(2), 186–196. doi:10.1016/j.ijpe.2011.04.004

Khaleeq uz Zaman, U., Siadat, A., Rivette, M., Baqai, A. A., & Qiao, L. (2017). Integrated product-process design to suggest appropriate manufacturing technology: A review. *The International Journal of Advanced Manufacturing Technology, 91*(1), 1409-1430.

Koufteros, X. A., Vonderembse, M. A., & Doll, W. J. (2002). Integrated product development practices and competitive capabilities: The effects of uncertainty, equivocality, and platform strategy. *Journal of Operations Management*, *20*(4), 331–355. doi:10.1016/S0272-6963(02)00018-9

Levandowski, C., Michaelis, M. T., & Johannesson, H. (2014). Set-based development using an integrated product and manufacturing system platform. *Concurrent Engineering, Research and Applications*, *22*(3), 234–252. doi:10.1177/1063293X14537654

March-Chorda, I., Gunasekaran, A., & Lloria-Aramburo, B. (2002). Product development process in Spanish SMEs: An empirical research. *Technovation*, *22*(5), 301–312. doi:10.1016/S0166-4972(01)00021-9

Moffat, L. K. (1998). Tools and teams: Competing models of integrated product development project performance. *Journal of Engineering and Technology Management*, *15*(1), 55–85. doi:10.1016/S0923-4748(97)00027-1

Monplaisir, L. (1999). An integrated CSCW architecture for integrated product/process design and development. *Robotics and Computer-integrated Manufacturing*, *15*(2), 145–153. doi:10.1016/S0736-5845(99)00009-5

Mulebeke, J. A., & Zheng, L. (2006). Incorporating integrated product development with technology road mapping for dynamism and innovation. *International Journal of Product Development*, *3*(1), 56–76. doi:10.1504/IJPD.2006.008875

Ottosson, S. (2002). Virtual reality in the product development process. *Journal of Engineering Design*, *13*(2), 159–172. doi:10.1080/09544820210129823

Parker, H. (2000). Interfirm collaboration and the new product development process. *Industrial Management & Data Systems*, *100*(6), 255–260. doi:10.1108/02635570010301179

Rauniar, R., Doll, W., Rawski, G., & Hong, P. (2008). Shared knowledge and product design glitches in integrated product development. *International Journal of Production Economics*, *114*(2), 723–736. doi:10.1016/j.ijpe.2008.03.005

Schilling, M. A., & Hill, C. W. (1998). Managing the new product development process: Strategic imperatives. *The Academy of Management Perspectives*, *12*(3), 67–81. doi:10.5465/ame.1998.1109051

Smith, R. P., & Morrow, J. A. (1999). Product development process modeling. *Design Studies*, *20*(3), 237–261. doi:10.1016/S0142-694X(98)00018-0

Sommer, A. F., Dukovska-Popovska, I., & Steger-Jensen, K. (2014). Barriers towards integrated product development: Challenges from a holistic project management perspective. *International Journal of Project Management*, *32*(6), 970–982. doi:10.1016/j.ijproman.2013.10.013

Song, X. M., Neeley, S. M., & Zhao, Y. (1996). Managing R&D-marketing integration in the new product development process. *Industrial Marketing Management*, *25*(6), 545–553. doi:10.1016/S0019-8501(96)00069-7

Srinivasan, V., Lovejoy, W. S., & Beach, D. (1997). Integrated product design for marketability and manufacturing. *JMR, Journal of Marketing Research*, *34*(1), 154–163. doi:10.1177/002224379703400113

Tidd, J., & Bodley, K. (2002). The influence of project novelty on the new product development process. *R & D Management*, *32*(2), 127–138. doi:10.1111/1467-9310.00245

Tzokas, N., Hultink, E. J., & Hart, S. (2004). Navigating the new product development process. *Industrial Marketing Management*, *33*(7), 619–626. doi:10.1016/j.indmarman.2003.09.004

Wind, Y., & Mahajan, V. (1988). New product development process: A perspective for reexamination. *Journal of Product Innovation Management*, *5*(4), 304–310. doi:10.1111/1540-5885.540304

Xie, S. Q., Tu, P. L., Aitchison, D., Dunlop, R., & Zhou, Z. D. (2001). A WWW-based integrated product development platform for sheet metal parts intelligent concurrent design and manufacturing. *International Journal of Production Research*, *39*(17), 3829–3852. doi:10.1080/00207540110072290

Ye, X., Liu, H., Chen, L., Chen, Z., Pan, X., & Zhang, S. (2008). Reverse innovative design - an integrated product design methodology. *Computer Aided Design*, *40*(7), 812–827. doi:10.1016/j.cad.2007.07.006

Zahay, D., Griffin, A., & Fredericks, E. (2004). Sources, uses, and forms of data in the new product development process. *Industrial Marketing Management*, *33*(7), 657–666. doi:10.1016/j.indmarman.2003.10.002

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