

Automotive Process-based New Product Development: A Review of Key Performance Metrics

Komsan Sanongpong

Abstract— The new product development (NPD) is the process by which a new product idea is conceived, investigated, taken through the design process, manufactured, marketed and serviced. In the automotive industry, within the context of ISO/TS16949:2002 (the automotive quality management system international standard), these related to the product realization process (PRP) which consists of five phases: “Plan and Define Program”, “Product Design and Development”, “Process Design and Development”, “Product and Process Validation”, and “Production Launch, Feedback Assessment and Corrective Action”. These phases may be done concurrently and have correlated activities. This paper proposes a process-based management concept focusing on controlling and measuring for their effective management including literature review of NPD performance metrics. Integrating the process-based management concept with the proper performance measure can initiate new knowledge which will contribute to the improvement of the automotive industry.

Index Terms—new product development (NPD), metrics, process-based management, product realization process (PRP)

I. INTRODUCTION

The product quality planning, which is sometimes used interchangeably with new product development (NPD), however, the second one seemed to represent the broader term, is the process by which a new product idea is conceived, investigated, taken through the design process, manufactured, marketed and serviced through obsolescence. Reference [23] noted that, the competitive advantage of a company can be linked to two key factors: (i) the ability to generate new intellectual property that offers superior value to customers and (ii) the ability to capitalize on it quickly. Superior quality and project management optimize the performance excellence of organizations, unfortunately, the combined leverage of quality and project management is often underutilized due to inadequate related knowledge and experience, time pressures or budgetary cutbacks [29]. Reference [25] describes the quality planning road map as the activity determining customer needs and developing the products and processes required to meet those needs. The Automotive Quality Management System (QMS) International Standard, ISOTS16949:2002, the particular requirements for the application of ISO 9001:2000 [21] for automotive production and relevant service part organizations, defined “Product Realization Process (PRP)”

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as one of major parts of the standard, a useful framework for understanding the product quality planning in general. Reference [7] defined the methodology for managing new product development, Advance Product Quality Planning (APQP), in the automotive supply chains. ISO/TS16949:2002 determines this as one of the means to achieve the PRP (NPD)’s objectives. Since it is published, the APQP play an important role in the automotive industry worldwide, especially in Thailand, as it appeared to be significantly practical to the NPD team. In other words, implementing the PRP without more specific methodology like APQP, especially for the local companies in Thailand, result in less competitiveness to the market.

The APQP embodies the concepts of error prevention and continual improvement in contrasted to error detection, and is based on a multidisciplinary approach. The APQP consists of five phases as follows (see Fig. 1): Phase 1 - Plan & Define Program. Phase 2 - Product Design and Development. Phase 3 - Process Design and Development. Phase 4 - Product and Process Validation. Phase 5 - Production Launch, Feedback Assessment and Corrective Action. In real practice, these phases may overlap and many tasks are done in parallel (concurrent engineering) to streamline and maximize resource utilization. Fig. 2 describes the rationale how customer requirements are deployed and communicated to all levels of the organization in the PRP (NPD). The purpose of this paper is to set the scope and conduct literature review for further study under Process-based New Product Development Performance on the Automotive Industry in Thailand, it also sought to determine the need for performance measurement during the NPD process and reveal which measures are

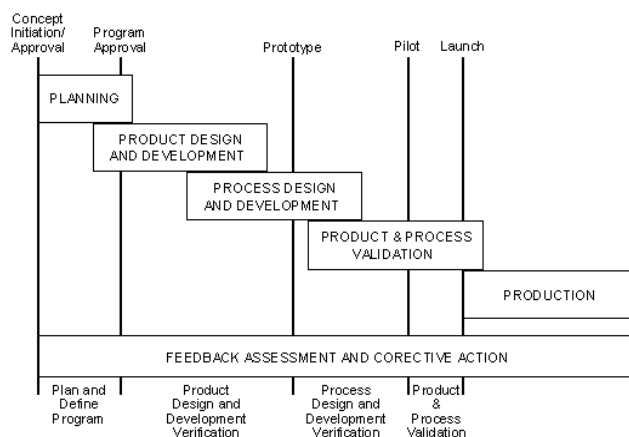


Fig. 1 APQP Phases (AIAG, 1995)

currently used, which further measures are needed and where improvements can be made, based on automotive process-based management proposed by the author.

II. MANAGING THE PROCESS-BASED NPD

One of the most important keys of success of NPD are interest, commitment and support of management. Reference [5] described the preferred characteristics of NPD which is developing under the direction of top management. Reference [12] defined the NPD significant characteristics which are repeatable to effectively communicate to team with consistent use of the defined process and flexible to tailor to the different needs. The most important task in improving the development program is improving the communication between the development team and the management [8]. Since NPD are based on information content and their accompanying information-dominated methods, an efficient methodology for reducing NPD time initially requires developing an understanding of information flow among different project processes [1]. The trend in organizational structures for high performance product development organizations has moved toward integrated models [13], [31], support by cross functional teams that know how to manage their knowledge and communication boundaries effectively [2]-[3], [4]. Benefit from applied research are greatest when the NPD process is closely integrated with the operations of a firm and motivated by the problems and opportunities it faces, this integration can enable a superior product development process overall, if the limiting factors it introduces are addressed successfully [23]. The study of the effect of Transaction Memory System (TMS) on NPD outcomes including mediating and moderating factors, i.e. the collective mind and environment turbulence, respectively found that: 1) TMS has positive impact on team learning and speed-to-market; 2) the collective mind (i.e. team members' attention to interrelating actions) mediates relations between the TMS, team learning, and speed-to-market; and 3) team learning and speed-to-market mediates relations between the TMS and new product success [6]. A TMS indicates who will learn what and from whom. Reference [27] described the meaning of concurrent engineering that is the process of designing a product using all inputs and evaluations simultaneously and early during design to ensure that internal and external customers' needs are met. This takes a major role in the NPD. Real change cannot be accomplished in a large organization without the impetus of a facilitator. Enterprise wide training programs, supported by top management, were necessary including effective tools used by the facilitator. The study conducted on 67 industrial organizations in

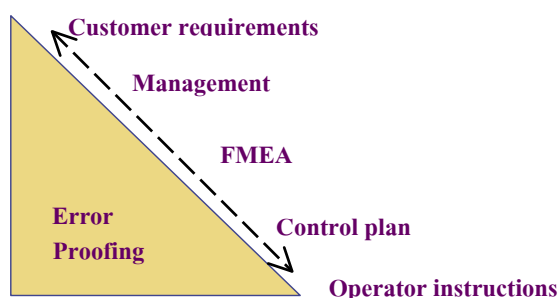


Fig. 2 PRP (NPD) Rationale

Singapore shown that brainstorming is the most commonly used tool, however, benchmarking, DOE, and FMEA are also applied by more than half of the respondents [10]. Competence in the resource based perspective represents a combination of knowledge, skills and technologies which provide opportunities for the NPD and are difficult for competitors to duplicate. To pursue growth opportunities, the organization must now focus on the management of their abilities in product and technology development and the production expertise, while directing complementary human and physical investment [30]. Reference [20] addressed the methodology used to determine the amount of human resources needed to develop products. According to a knowledge-based view of organizations, the principle function of a firm is the creation, integration, and application of knowledge [38]. A successful NPD strategy involves the identification, development and exploitation of key resources. Such exploitation of a firm's unique knowledge base ultimately leads to successful new products and, in turn, sustainable competitive advantage [17], [34]. Information technology is also a catalyst of fundamental changes in the strategic structure, operations, and management of organizations (including the NPD), due to their highly capabilities [40]. The NPD is a dynamic process driven by continual improvements. The NPD should be adapted constantly to changing environment, its own organization, and customer needs for sustainable success. The involvement of customers and suppliers in the whole NPD life cycle through e-commerce technologies is a promising and possible approach of mass customization that has the potential of reaping substantial benefit [35]. In a product development chain, cost control through a proper or optimal plan and a selection of various NPD or suppliers are very critical to the success of customization [39]. Customer capability enhancement and contributor assessment, appreciation and renewal after project termination at the closure stage promote customer delight and referrals, organizational accountability and proud, grateful, re-energized contributors to future projects [29]. In Thailand, the automotive industry's methodologies used to monitor the performance of the NPD are not suitably defined which lead to poor performance of NPD. This paper, within the context of ISO/TS16949:2002 (the automotive quality management system international standard), proposed the process-based management strategies in managing the PRP (NPD) focusing on controlling and measuring. There are two rationales behind the strategies. First, the PRP (NPD) is controlled to help assure the desired results and lead to continual improvements. Second, the PRP (NPD) performance is measured to assure an adequate level of performance through establishment of appropriate metrics.

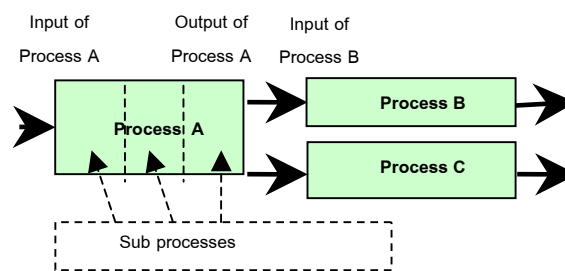


Fig. 3 processes linkages

1) Controlling

“...The management shall review the product realization process and the support processes to assure their effectiveness and efficiency [22]....” The NPD is subjected to be controlled to help assure the desired results in terms of both effectiveness and efficiency. These controls are in the form of design reviews including verifications and validations as part of the review. The requirements of design and development review, verification and validations are identified in the ISO/TS16949:2002 standard under the PRP (NPD) part. Design and development reviews focus on addressing the technical requirements of the development program and the business progressive requirements. In order to control the NPD through its review, verification and validation, it is necessary to understand the process-based QMS. The ISO/TS16949:2002 standard applied the concept of “process approach” to enhance customer satisfaction by meeting customer requirements. An activity using resources, and managed in order to enable the transformation of inputs into outputs, can be considered as a process [21]. A process may comprise of many sub-processes/activities depending on how we identify the process. Often the output from one process directly forms the input to the next (see Fig. 3 processes linkages). The application of a system of processes within an organization, together with the identification and interactions of these processes, and their management, can be referred to as the “process approach” [21]. An advantage of the process approach is the ongoing control that provides over the linkage between the individual processes within the system of processes, as well as over their combination and interaction.

In real practice, especially in the nature of automotive industry, an organization can classify the processes exists in the Quality Management System (QMS), including the PRP (NPD) into three categories;

- Core/Customer Oriented Process (COP), the processes whose output influence directly to the customer satisfaction. (Typically these processes are bid and tender, contract review, design and development, manufacturing, and delivery etc.)
- Support Process, the processes whose output support the COPs and other support processes to function properly. (Typically these processes are training, purchasing, and maintenance etc.)

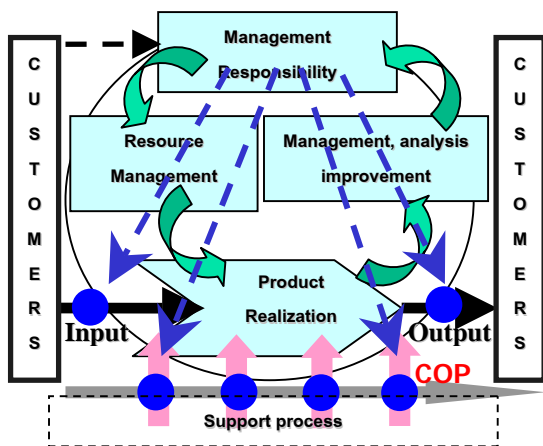


Fig. 4 QMS model (modified from model of process-based quality management system, ISO9001:2000)

- Management Process, the process of review and monitoring to all COPs and support process to assure their efficiency and effectiveness (typically this is done through management review and internal audit)

Fig. 4 describes how PRP (NPD) interacts with customer and other processes in the QMS including management process. It also shows that PRP (NPD) is comprise of COPs and support processes as describe above. Fig. 5 focuses on management monitoring over COP and support process in the organization. The monitoring may includes design review, verification and validation. Design reviews including verifications and validations are formal reviews conducted during the development program to assure that the metrics, requirements, concept, and product or process satisfies the requirements of that stage of development, the issues are understood, the risks are being managed, and there is a good business case for development. Typical design reviews include: requirements review, concept/preliminary design review, final design review, and a production readiness/launch review including program’s progress according to customer timing requirement. Reference [26] described that, under the design review concept, those who will be impacted by the design are given the opportunity to review the design during various formative stages. Design and development verification as part of the review should be performed in accordance with planned arrangements to ensure that the design and development outputs have met the design and development input requirements. Design verification is testing to assure that the design outputs meet design input requirements. Design verification may include activities such as: design reviews, performing alternate calculations, understanding and performing tests and demonstrations, and review of design documents before releasing. The verification for the NPD should focus on the inputs and outputs of each phase of the NPD including applicable customer requirements according to the customer timing program. Design and development validation as part of the review that mainly involved on PRP (NPD) phase 4 is performed in accordance with planned arrangements to ensure that the resulting product and manufacturing process is capable of meeting the requirements for the specified application or intended use. The validation should be completed prior to the delivery or implementation of the product. Product design validation is performed on the final product design with parts that meet design intent produced from manufacturing processes from PRP (NPD) phase 4 intended for normal production. Both of product and process validation/testing data are compiled together and submit

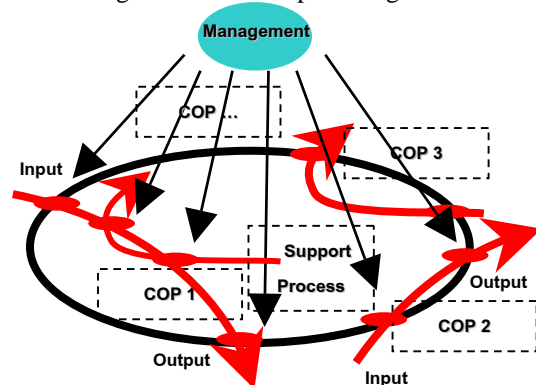


Fig. 5 QMS Monitoring

to customer for approval through production part approval process (PPAP) agreed by the customer. Production part approval process is normally subsequent to the verification of the manufacturing process. The validation normally includes an analysis of field reports for similar products. Design and development validation is performed in accordance with customer requirements including program timing. The validation is officially complete when the relevant data, submitted to customer through PPAP, are approved. The control of process-based NPD which is performed through design reviews including verifications and validations as demonstrated above is to assure the desired results in terms of both effectiveness and efficiency with the involvement of the development team and the management. Fig. 6 is the extended illustration of Fig. 4 focused on the PRP (NPD) specifically. It describes the components of PRP (NPD) which is divided into 5 phases from the beginning till the end of the development process as describes in the introduction of this paper. The (PRP) NPD can be classified as COP which includes many sub-processes inside. Fig. 6 also shows the example of support processes e.g. purchasing, training and maintenance etc. These support processes are to be controlled together with the COP as well. The success of the NPD is depending on how the NPD is controlled and how the control results is led to the improvements. One of the key of success for managing the NPD is determining the proper metrics together with effective control to assure the desired result. In doing so, the process analysis is necessary. Fig. 7 describes this concept. The turtle diagram is an effective tool for process analysis. This diagram focus on six components linked to the process as follows: What, Who, How, How Much, Input, Support Process and Output. Perhaps, the most important one is the "How Much" which is addressed with metrics. While monitoring the process under the process approach, the management is supposed to review the process metrics in order to control the whole process to deliver the desired output. Depending on the resulting achievement of the metrics, the corrective action and/or improvement action then can be properly initiated. The root causes of problems encountered usually come from one or more of the process components, sometimes even the metrics itself is the cause of problem. This insists the significant role of the measuring dimension in managing the process-based NPD.

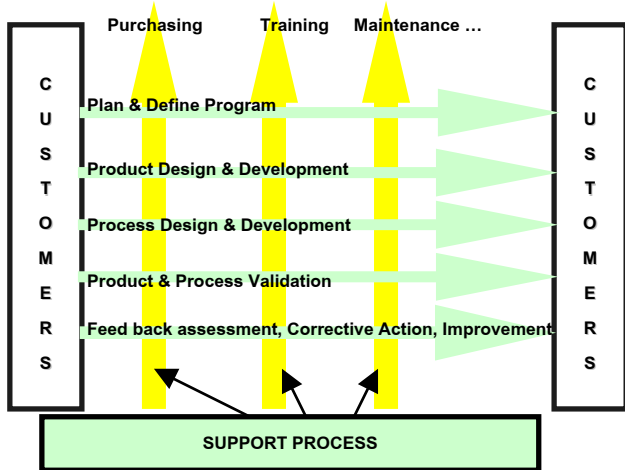


Fig. 6 Product realization process in detail

2) Measuring

Traditional Measures

The NPD process performance is measured to assure an adequate level of performance through establishment of product, process and program performance metrics. These are needed to set goals and lead to controls and improvements. Proper metrics need to be selected. Improper metrics can optimize the performance at the over expense of cost, require significant effort to collect data and develop without providing meaningful information of any real benefit. Criteria for effective metric typically include: simple, understandable, logical and repeatable. Some simple target areas of successful product development efforts [41] included product cost, product quality, development capability, development cost, and development time. ISO/TS16949:2002 defined the criteria as follows: measurable, consistent with organization goal, based on business objectives and the business process, address customer expectation, and achievable within a defined time period. Selecting the suitable metrics is very crucial in measuring the NPD. Traditionally NPD competitive capabilities have been measured on the basis of lead times, productivity, and conformance quality [24].

Reference [36] noted that in an uncertain product development, cross-functional integration can have a positive impact on the financial performance of new products. The metric success factors can includes; management become more aware of their quantitative information requirements, work centre becomes process driven, metrics are integrated into daily practice, measures are oriented to achieve objectives, processes are managed from the numbers, and management uses the measure to improve capabilities. Most of development programs failed because they are not focused on business issues and do not have metrics that drive improvements [9]. Reference [24] found that, using data from a large sample of NPD, the result support the claim that simultaneous pursuit of multiple competitive capabilities enhances NPD success. For example, time-to-market and conformance quality were directly and significantly related to all measures of NPD success. Also, the interactions of conformance quality and cost, conformance quality and time-to-market, and product cost and time-to-market were found to influence different measures of NPD success.

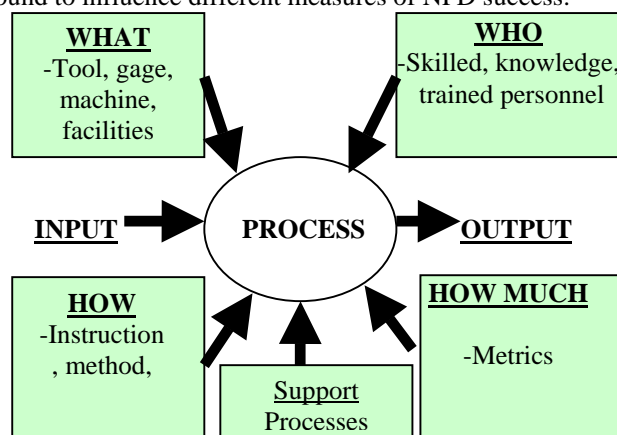


Fig. 7 Process Analysis-Turtle Diagram

Reference [11] proposed four basic types of metrics for NPD as follows; Process metrics, Product metrics, Program metrics, and Business metrics etc.

However, significant arguments against traditional measures of NPD process performance have been presented. For example, they are frequent based on outdated cost management systems with “lagging” metrics, not related to corporate strategy and not supporting to continuous improvement [16], [28]. Reference [32] stated that, the measures promote short-termism and local optimization, while missing to provide data on customer needs, responsiveness and competitors in global markets. Both academics and practitioners agree that reliance on international financial measure of NPD performance is inadequate for today’s operating environment [18], [28].

As literature review summary of previous studies [19], [42], [15], measures used to evaluate an organization’s performance, including NPD, have traditionally been largely financial, based on management accounting systems. These measures have been used for long time because they are easily understood, familiar to senior management and can be easily addressed. Financial measures also have the advantage of being “precise and objective” [33]. NPD process measures used in many organizations currently are often lagging indicators, only concerned with revising the outcome of the individual project and integrated NPD effort, rather than providing guidance on what needs to be consistently measured to ensure they are successful [37]. Success in NPD is usually evaluated along multiple metrics. Apart from evaluating the success of the NPD (measured by the attainment of NPD competitive capabilities), management are also interested in the overall impact of NPD on the business as measured by profitability, break event point, and initial market penetration [24]. Reference [18] concluded that, the best measures of NPD success are some combination of market share, profitability and customer satisfaction. Reference [37] sought to determine the need for performance measurement during the NPD process and reveal which measures are currently used, which further measures are needed and where improvements can be made. The studies provided an interesting comparison of company measurement practices and increased our understanding of how performance measurement has developed in the intervening period (from 1996 to 2001). Based on these results, together with the outcomes of the case study discussion [14], the study stated that the lack of measures that assist with NPD is still adversely affecting company performance and hence future success. A more rounded evaluation of NPD projects requires operational measures that dynamically track progress and performance (leading metrics), preferably on a real-time basis, indicating an appropriate course of action to ensure that the outcome of the process is successful [37]. Based on the literature reviews, the NPD performance measurement has been changing from lagging indicators to organization integrated indicator. Increasingly, it is also tend to move from accounting based to customer oriented such as customer need and customer satisfaction.

According to the author’s experience as ISO/TS16949 certified auditor/consultant. In Thailand, especially during year 2003-2005, the period of which the ISO/TS16949:2002 is newly introduced to the country and until now, many

companies in the automotive industry set up the improper metrics e.g. the metrics is not represented the actual process function, the metrics is not established for key process etc., these led to failures of establishing the automotive quality management system and/or maintaining its effectiveness. Furthermore, although the turtle diagram (see Fig. 7) is an effective analysis tool, but it more focuses on each process/phase with less focus on how it influences to others. In the real practice, in order to achieve the desired output, the NPD must be managed as all processes/phases are linked together under the process-based approach. Improvement concept such as Plan-Do-Check-Action (PDCA) cycle can be applied to foster managing the NPD as a whole picture. **Plan:** establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization’s policies. **Do:** implement the processes. **Check:** monitor and measure processes and product against policies, objectives and requirements for the product and report the results. **Act:** take actions to continually improve process performance. The first three stages are devoted to the up-front development and planning process through product and process validation. Lastly, Act is the implementation phase - focusing on customer satisfaction and continual improvement. The NPD is then being managed by the two-dimension improvement guideline, the process analysis-turtle diagram plus the PDSA cycle. These dynamic actions will promote the continual improvements.

III. CONCLUSION

Based on the literature reviews, the NPD performance measurement is increasingly focused on the customer need and customer satisfaction, rather than the accounting-based system. This will lead to the significant change of area of interest on both theoretical and practical in the near future. The author also proposes the process-based management concept within the context of the automotive quality management system standard, ISO/TS16949:2002. Integrating the process-based management concept with the proper performance measure can initiate new knowledge which will contribute to the improvement of the automotive industry. The further study of NPD performance measurement in conjunction with the automotive process-based management is recommended.

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