Automotive Product Realization; A Process-Based Management

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Abstract— **The product realization is the process by which a new product idea is conceived, investigated, taken through the design process, manufactured, marketed and serviced. This typically 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 or have correlated activities. Managing this improperly lead to poor process performance. This paper, within the context of ISO/TS16949:2002 (the automotive quality management system international standard), proposed a reviewed process-based management concept focusing on metrics and controls for their effective management. The purpose of this paper is to set the scope and conduct literature review for further in-depth study under the topic of "Automotive Process-Based Management Analysis through Relation between Organizations Structure and Product Realization Effectiveness: The Case of Automotive Suppliers in Thailand".**

Index Terms— **Controls, Metrics, Process-based, PRP.**

I. Introduction

The product quality planning is the process by which a new product idea is conceived, investigated, taken through the design process, manufactured, marketed and serviced through obsolescence. Reference [19] 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 [24]. Reference [21] describes the quality planning road map as the activity determining customer needs and developing the products and processes required to meet those needs. Other practitioners have invented and reinvented similar road maps. The Automotive Quality Management System (QMS) Inter national Standard, ISOTS16949:2002, the particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations**,** defined "Product Realization Process (PRP)" 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 in the automotive supply chains. ISO/TS16949:2002 determines this manual as one of the means to achieve the PRP's objectives. 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**. This includes determining customer needs, requirements and expectations using tools such as Quality Function Deployment (QFD) to organize those needs and translate them into product characteristics/requirements, review the entire quality planning process to enable the implementation of a quality program. The outputs include design goals, reliability and quality goals etc. **Phase 2 - Product Design and Development**. This includes review of the inputs and executes the outputs, which include failure mode and effect analysis (FMEA), design verification, design reviews etc. This also uses feedbacks from other similar projects with the objective of developing counter-measures on the current project. The outputs include design FMEA, reliability results, and product/material specifications etc. **Phase 3 - Process Design and Development**. This includes addressing process features for developing manufacturing process including related control plan, these tasks are depending on the successful completion of phase 1 and 2. The outputs include flow chart, process FMEAs, control plan, instructions etc. **Phase 4 - Product and Process Validation**. This phase is performed to validate the product and selected manufacturing process including its control mechanisms. This also provides outlining further production conditions and requirements identifying the required outputs. The product validation/testing are conducted on the resulting products from the process study. The outputs include objectives for manufacturing process capability, reliability, maintainability and availability, as well as acceptance criteria etc.

Phase 5 - Production Launch, Feedback Assessment and Corrective Action. This phase focuses on reduced variation, corrective action, and continual improvement, identifying feed back and links to customer expectations and future product programs.

In real practice, these phases may overlap and many tasks are done in parallel (concurrent engineering) to streamline and maximize resource utilization. Fig. 2. PRP Rationale describe the rationale how customer requirements are deployed and communicated to all levels of the organization in the PRP.

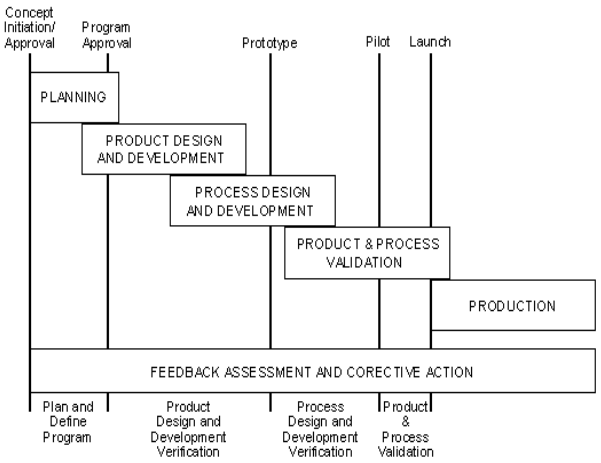

Fig. 1. APQP Phases (AIAG, 1995)

The purpose of this paper is to set the scope and conduct literature review for further in-depth study under the topic of "Automotive Process-Based Management Analysis through Relation between Organizations Structure and Product Realization Effectiveness: The Case of Automotive Suppliers in Thailand".

2. Managing the product realization process (PRP)

In Thailand, the automotive industry's methodologies used to monitor the performance of the PRP are not suitably defined which lead to poor performance of PRP. 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 focusing on metrics and controls. There are two rationales behind the strategies. First, the PRP performance is measured to assure an adequate level of performance through establishment of appropriate metrics. Second, the PRP is controlled to help assure the desired results and lead to continual improvements.

2.1 Metrics

The PRP 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 [33] 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 PRP. Traditionally PRP competitive capabilities have been measured on the basis of lead times, productivity, and conformance quality [20]. Reference [11] proposed four basic types of metrics for PRP as follows;

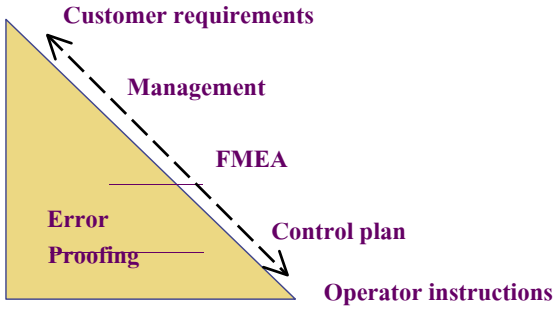

Fig. 2. PRP Rationale

Process metrics - short-term metrics that measure the effectiveness of the PRP and used to predict program and product performance e.g. cost of poor quality, unit production cost, and process capability etc., ***Product metrics*** - medium-term metrics that measure effectiveness in meeting product objectives/technical performance measures; Generic Design - e.g. mean time between failure, Electrical Design - e.g. number of design review changes/total terminations, Mechanical Design – e.g. number of in-process design changes/number of parts, Software Engineering – e.g. man-hours/1,000 software lines of code etc., ***Program metrics*** - medium-term metrics that measure effectiveness in executing the development program e.g. actual staffing (hours or headcount) vs. plan, personnel turnover rate, % of milestone dates met, and schedule performance etc., ***Business metrics*** - longer term metrics that measure the effectiveness of the enterprise in developing new products e.g. breakeven time or time-to-profitability etc. 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 [20] found that, using data from a large sample of PRP, the result support the claim that simultaneous pursuit of multiple competitive capabilities enhances PRP success. For example, time-to-market and conformance quality were directly and significantly related to all measures of PRP 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 PRP success.

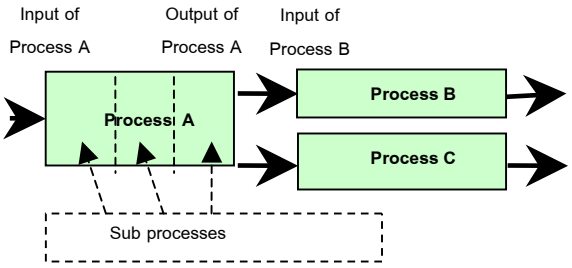

Fig. 3 processes linkages

2.2 Controls

"…The management shall review the product realization process and the support processes to assure their effectiveness and efficiency [18]…" The PRP 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 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 PRP 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 [17]. 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" [17]. 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 into three categories;

- 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.)

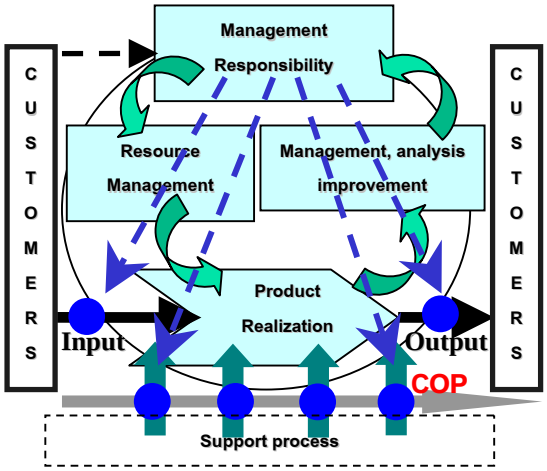

Fig. 4 QMS functioning (a)

- 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. QMS functioning (a), describes how PRP interacts with customer and other processes in the QMS including management process. It also shows that PRP is comprise of COPs and support processes as describe above. Fig. 4 QMS functioning (b), simply focusing on management controlling over COP and support process in the organization. Fig. 5 is the extended illustration of Fig. 4 focused on the PRP itself. It describes the components of PRP 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 can be classified as COP which includes many sub-processes inside. Fig. 5 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. **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 [22] 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 PRP should focus on the inputs and outputs of each phase of the PRP including applicable customer requirements according to the customer timing program. **Design and development validation** as

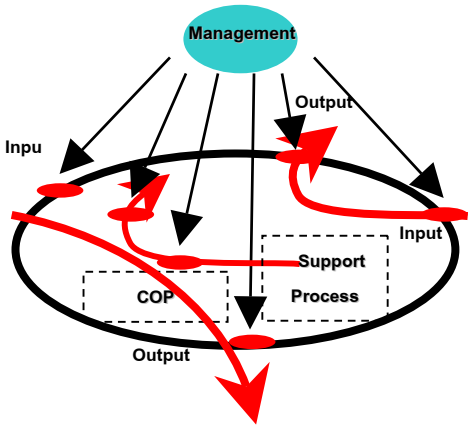

Fig. 4 QMS functioning (b)

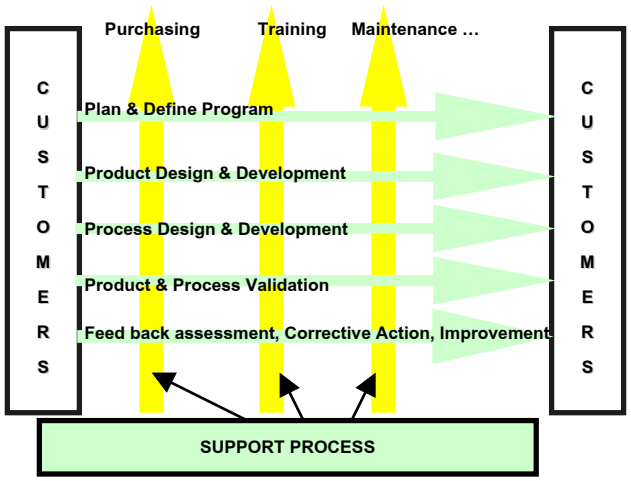

Fig. 5 Product realization process in detail

part of the review that mainly involved on PRP 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 phase 4 intended for normal production. Both of product and process validation/testing data are compiled together and submit to customer for approval trough 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 approach PRP 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. The success of the PRP is depending on how the PRP is controlled and how the control results is led to the improvements. One of the key of success for managing the PRP is determining the proper metrics together with effective control to assure the desired result. In doing so, the process analysis is necessary. Fig. 6. Process Analysis-Turtle Diagram describe 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 route causes of problems encountered usually come from one or more of the process components, sometimes even the metrics itself is the cause of problem. In Thailand during year 2003-2004, the period of which the ISO/TS169:2002 is newly introduced to the country, 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. However, although the turtle diagram is an effective analysis tool, but it more focus 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 PRP must be managed as a whole picture that all processes/phases are linked together under the process approach. Improvement concept such as Plan-Do-Study-Action (PDSA) cycle can be applied to foster managing the PRP as a whole picture (see Fig. 7 PRP-PDSA cycle). 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. PDSA can be briefly described as follows [17]; **Plan**: establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies. **Do**: implement the processes. **Study**: 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 PRP 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.

3.CONCLUSION

Ones of the most important keys of success of PRP are interest, commitment and support of management. Reference [5] described the preferred characteristics of PRP which is developing under the direction of top management. Many companies applied a good PRP system but resulting in failure because of lack of understanding and commitment from top management. Reference [12] defined the PRP significant characteristics which are repeatable to effectively communicate to team with consistent use of the defined

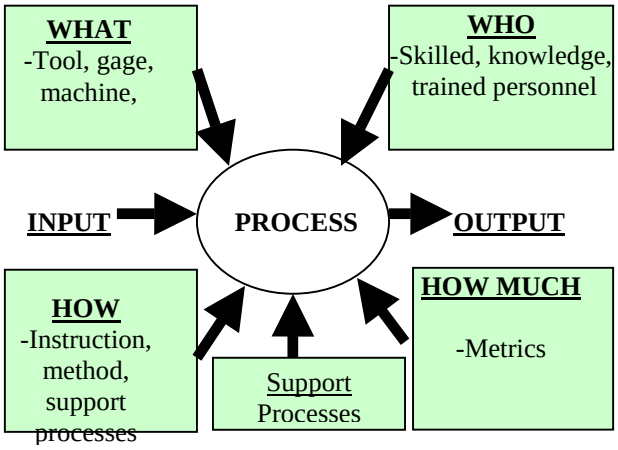

Fig. 6. Process Analysis-Turtle Diagram

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 PRP are based on information content and their accompanying information-dominated methods, an efficient methodology for reducing PRP 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], [26], 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 R&D 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 [19]. The study of the effect of Transaction Memory System (TMS) on PRP 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. The notation is that knowledge is distributed among people in the group, and to make effective use of it, individuals need to know who knows what. Reference [23] 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 PRP. 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 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 PRP 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 [25]. Reference [16] 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 [30]. A successful PRP 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 [14], [28]. Information technology has become the major facilitator of business activities in the world today. Information technology is also a

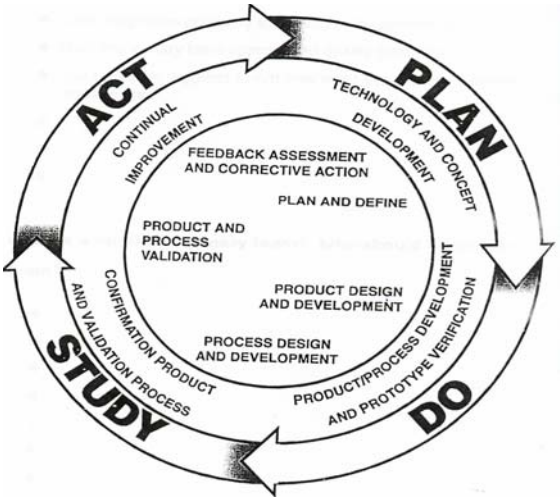

Fig. 7 PRP-PDSA cycle (AIAG, 1995)

catalyst of fundamental changes in the strategic structure, operations, and management of organizations (including the PRP), due to their highly capabilities [32]. The PRP must be specifically managed for each organization especially those who implement the ISO/TS16949 quality management system. Key of successes for one organization may not be practical for another because of organizational, technological, or cultural differences. The PRP is a dynamic process driven by continual improvements. The PRP should be adapted constantly to changing environment, its own organization, and customer needs for sustainable success. In the traditional paradigm, customization is in conflict with mass production with respect to PRP lead-time and cost. Normally, a tradeoff must be made between customization and low cost through mass production. However, the rapid development of computer and internet communication technologies, concurrent engineering and modular design technology are starting to allow for a greater involvement of customers and suppliers in the development of a product, which formulates a value chain and is called the product development chain or product-oriented supply chain. The

involvement of customers and suppliers in the whole PRP life cycle through e-commerce technologies is a promising and possible approach of mass customization that has the potential of reaping substantial benefit [29]. In a product development chain, cost control through a proper or optimal plan and a selection of various PRP or suppliers are very critical to the success of customization [31]. 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 [24]. Success in PRP is usually evaluated along multiple metrics. Apart from evaluating the success of the PRP (measured by the attainment of PRP competitive capabilities), management are also interested in the overall impact of PRP on the business as measured by profitability, break event point, and initial market penetration [20]. Reference [15] concluded that, the best measures of PRP success are some combination of market share, profitability and customer satisfaction.

References

[1] Abdelsalam, H. M. E. and Bao, H. P., **A Simulation-Based Optimization Framework for Product Development Cycle Time Reduction,** *IEEE Transactions on Engineering Management***,** Vol. 53, No. 1, pp. 69, 2006.

[2] Ancona, D.G., and Caldwell, D., **Improving the performance of new product teams,** *Research Technology Management*, 33 (2), pp. 25-29, 1990.

[3] Ancona, D.G., and Caldwell, D., **Bridging the boundary: external activity and performance in the organizational teams,** *Administrative Science Quarterly* 37 (4), pp. 634-665, 1992.

[4] Ancona, D., Bresman, H., and Kaeufer, K., **The comparative advantage of X-teams**, *MIT Sloan management Review* 43 (3), pp. 33-39, 2002.

[5] Anderson, D. O., **Product Realization Process (PRP)**, *Louisiana Tech University, Article*, (http://web.archive.org/web/20040313141032/http://www2.latech.edu/~dalea/instruction/prp.html), 1998, accessed 10/05/07

[6] Akgun, A. E., Byrne, J. C. Keskin, H. and Lynn, G. S., **Transactive Memory System in New Product Development Teams,** *IEEE Transactions on Engineering Management*, Vol. 53, No. 1, pp. 95, Feb. 2006.

[7] Automotive International Action Group (AIAG), **Advanced Product Quality Planning and Control Plan**, *Reference Manual*, AIAG, 1994.

[8] Blake, Stewart P., **Managing for responsive research and development,** San Francisco, W.H. Freeman and Company, pp. 232-238, 1978.

[9] Boath, David B. and Bodnarczuk, Mark, edited by Roberts, George W., **Quality Planning, Control, and Improvement in Research and Development**, New York, Marcel Dekker, Inc., pp. 323-348, 1995.

[10] Chai, K. and Xin, Y., **The Application of New Product Development Tools in Industry: The Case of Singapore,** *IEEE Transactions on Engineering Management***,** Vol. 53, No. 4, pp. 552, Nov. 2006.

[11] Crows, Kenneth, **New Product Development Solutions**, DRM Associates, Article2001, (www.npd-solutions.com/pdmetrics.html), accessed 1/5/07

[12] Crows, Kenneth, **New Product Development Solutions**,DRM Associates, Article, (www.npd-solutions.com/pdprocess.html), 2001, accessed 5/5/07

[13] Daft, R.L., **Organization Theory and Design,** 8th edition, Mason, South-Western (Thomson), pp. 656, 2004.

[14] Gopalakrishan, S. and Bierly, P. E., **The impact of Firm Size and Age on Knowledge Strategies During Product Development: A study of Drug Delivery Industr**y, *IEEE Transactions on Engineering Management***,** Vol. 53, No. 1, pp. 3, Feb. 2006.

[15] Griffin, A., and Page, A. L., **PDMA success measurement project: Recommended measures for product development success and failure,** *J. Product Innovation Manage.*, Vol. 13, pp.478-496, 1996.

[16] Holtta-Otto, K. and Magee, C. L., **Estimating Factors Affecting Project Task Size in Development-An Empirical Study**, *IEEE Transactions on Engineering Management***,** Vol. 53, No. 1, pp. 86, Feb. 2006.

[17] International Organization for Standardization (ISO), **ISO9001:2000: quality management system standard**, Geneva, ISO, 2000.

[18] International Organization for Standardization (ISO), **Technical Specification ISOTS16949:2002**, **the particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organizations**, 2nd edition, Geneva, ISO, 2002.

[19] Jablokow, K.W. and Booth, D.E., **The impact and management of cognitive gap in high performance product development organizations,** *J. of Engineering and Technology Manag.*, Vol. 23 No. 4, pp. 332, Dec. 2006,

[20] Jayaram, J. and Narasimhan R., **The Influence of New Product Development Competitive Capabilities on Project Performance,** *IEEE Transactions on Engineering Management***,** Vol. 54, No. 2, pp. 241, 243, May 2007.

[21] Juran, J. M., **Juran on leadership for quality: an executive handbook**, New York, THE FREE PRESS, pp. 81-144, 1989.

[22] Juran, J. M., **Juran on quality by design: the new steps for planning quality into goods and services,** New York, THE FREE PRESS, pp. 200-205, 1992.

[23] Juran, J. M. and Gryna Frank M., **Quality planning and analysis: from product development through use**, 3rd edition, Singapore, Mcgraw-Hill, pp. 279, 1993.

[24] Kloppenborg, Timothy J. and Petrick, Joseph A., **Managing Project Quality,** *IEEE Engineering Management Review*, Vol. 32, No. 4, pp. 86, 90. 4th Q., 2004.

[25] McDermott, C. and Coates T., **Managing Competencies in Breakthrough Product Development: A Comparative Study of Two Material Processing Projects**, *IEEE Transactions on*

Engineering Management, Vol. 54, No. 2, pp. 241, 348, May 2007.

[26] Nadler, D.A., Tushman, M.L., **Competing by design**, Oxford, UK, Oxford University Press, pp. 256, 1997.

[27] O'Grady, P. and Chuang, W. C., **Research issues in e-commerce and product development**, Int. J. Cybern. Syst., Vol. 32, pp. 775-796, 2001.

[28] Petaraf, M. A., **The cornerstones of competitive advantage: A resource-based view**, *Strat Manage. J.*, Vol. 14, pp. 179-191, 1993.

[29] Poirier, C. C. and Reiter, S. E., **Supply Chain Optimization: Building the Strongest Total Business Network,** San Francisco, CA, Berrett-Koehler, Inc, 1996.

[30] Spender, J. C., **Making knowledge the basis of a dynamic theory of the firm,** *Strat. Manage. J. (Winter Special Issue)*, Vol. 17, pp. 45-62, 1996.

[31] Tu, Y. L., Xie, S. Q., and Fung, R.Y. K., **Product Development Cost Estimation in Mass Customization**, *IEEE Transactions on Engineering Management,* Vol. 54, No. 1, pp. 29, Feb. 2007.

[32] Turban, E., Leidner D., Mclean E. and Wetherbe J., **Information Technology for Management: Transforming Organizations in the Digital Economy,** 6th edition, Asia, John Wiley & Sons, pp. 7, 2007.

[33] Ulrich, Karl T. and Steven D. Eppinger, **Product Design and Development**, 3rd edition, New York, McGraw-Hill, pp. 266 – 298, 2004.