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Integration of Quality Planning with the Product Development Process

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Abstract. Quality planning is a key element of product development, especially in automotive projects governed by Advanced Product Quality Planning (APQP) reference logic. The literature indicates that the main research gap is not the absence of APQP or quality planning methods, but the lack of a dedicated approach for assessing how mature APQP-oriented quality planning is cascaded and embedded across organisational layers. This article develops a conceptual model linking product development with product and process quality planning at the strategic, process, and operational levels. The study is based on a literature review, gap analysis, system analysis, and conceptual modelling. The contribution is the development of a three-layer integration model and the Quality Planning Integration Maturity Index (QPIMI), a matrix-based tool for maturity-oriented assessment. QPIMI is proposed as a complementary diagnostic layer, not as an alternative to APQP. The approach supports evidence-based self-assessment and provides a basis for further empirical validation.

Keywords: advanced product quality planning (APQP), process integration, knowledge management, maturity-oriented assessment

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JEL Classification: L23

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1. INTRODUCTION

Quality planning is a key element of new product development (Tang, 2021), particularly in industries where product and process decisions must be coordinated across engineering, quality, manufacturing, and customer-related functions. In this article,

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integration is understood as the alignment of quality objectives, quality planning methods, project decisions, and knowledge flows with the product development process. Such integration supports consistent decision-making and the reuse of quality-related knowledge across development stages.

Quality planning methods, such as Quality Function Deployment (QFD) and Failure Mode and Effects Analysis (FMEA), add value primarily when applied in a structured manner and coordinated with product development activities rather than used as isolated tools (Wolniak, 2018). In the automotive industry, this coordination is commonly organised within Advanced Product Quality Planning (APQP), which provides an established reference logic for planning, verifying, and approving product and process quality activities during development (AIAG, 2024). Therefore, the research problem addressed in this article is not the absence of APQP or individual quality methods, but the lack of a dedicated approach for assessing how mature APQP-oriented quality planning is cascaded and embedded across organisational levels. This includes translating strategic quality objectives into process-level planning, operational execution, feedback, and knowledge reuse. Recent studies on APQP phases also indicate that the effectiveness of quality planning depends on its alignment with project execution logic, project metrics, change management, and risk management (Rudolf & Roszak, 2024).

The aim of this article is to develop a conceptual model for integrating quality planning with the product development process and to propose a maturity-oriented assessment structure for evaluating this integration. The scientific contribution lies in conceptualising the organisational cascading of APQP-oriented quality planning across strategic, process, and operational levels. This assessment structure is later operationalised as the Quality Planning Integration Maturity Index (QPIMI). The study is theoretical and conceptual in nature and is based on a literature review, gap analysis, system analysis, and conceptual modelling.

2. LITERATURE REVIEW

Quality planning and product development are widely discussed in the literature on quality management and production engineering. Studies on integrated quality management emphasise the links between quality, suppliers, customers, technology, and personnel, including quality planning, process design, and continuous improvement (Foster, 2017). Other works point to the evolution of quality management and to the increasing complexity of internal and external organisational linkages (Weckenmann et al., 2015). However, these contributions mainly provide a functional or general quality management perspective and do not develop a dedicated model for integrating quality planning with successive stages of product development.

Research on continuous improvement, inspection, and maintenance also confirms the importance of a systemic approach to quality. Studies on Kaizen-based improvement projects identify critical success factors and their relationship with organisational performance (Gonzalez-Aleu et al., 2018), while research on quality inspection and maintenance highlights the need to coordinate inspection and preventive actions (Kurniati et al., 2015). These studies underline the process-oriented character of quality management, but they focus on selected organisational areas rather than on the integration of quality planning with the full product development cycle.

A separate research stream concerns maturity models for processes and management systems. Methodical approaches to maturity model design support the structured development and evaluation of organisational maturity structures (Becker et al., 2009; Hammer, 2007), while reviews of business process maturity models analyse their scope, structure and practical limitations (Röglinger et al., 2012; Tarhan et al., 2016). These models provide useful foundations for maturity-oriented assessment, but their primary focus is general process maturity, business process management, or IT-related maturity. They do not treat product and process quality planning as a separate assessment domain embedded in product development.

Organisational self-assessment and excellence frameworks provide another relevant foundation. ISO 9004:2018 supports self-assessment aimed at sustained organisational success (ISO, 2018), and the EFQM/RADAR logic is used for improvement-oriented assessment of management systems and organisational results (Suárez et al., 2016). In parallel, maturity model design literature emphasises the need to define the purpose, scope, levels, and assessment criteria of maturity models in a structured way (Becker et al., 2009; de Bruin et al., 2005). These approaches are useful for building an assessment logic based on maturity levels and evidence-based reflection. However, they remain general frameworks and do not provide a domain-specific structure for assessing how APQP-oriented quality planning cascaded across strategic, process, and operational levels.

The relationship between APQP and knowledge management has also been addressed in the literature. Previous studies propose knowledge management platforms supporting APQP and emphasise that APQP relies on both explicit and tacit project knowledge (Chiliban et al., 2014). Other research presents the integration of APQP tools with agent-based knowledge management systems in technologically complex environments (Wang et al., 2010). These contributions confirm the relevance of knowledge collection, structuring, and sharing in APQP-related activities, but they focus mainly on tool-oriented solutions rather than on a broader organisational model of quality planning integration.

Based on the literature review, previous studies most often address product and process quality planning, maturity assessment, and knowledge management as related but separate areas. They do not provide a dedicated approach for assessing how quality objectives are translated from the strategic level into process-level planning, operational execution, feedback, and knowledge reuse. The role of knowledge flows between these levels is also insufficiently developed (Roszak, 2016; Roszak & Jonda, 2020; Siwczyk & Roszak, 2021). Therefore, the research gap concerns the lack of a specialised maturity-oriented assessment structure for evaluating the integration of APQP-oriented quality planning with the product development process across strategic, process, and operational perspectives.

3. RESEARCH METHODOLOGY

The study is theoretical and conceptual. The starting point was a literature review covering product and process quality planning, organisational process maturity models, self-assessment approaches, and knowledge management. Knowledge management was treated not as a separate research object, but as a supporting perspective for analysing how quality-related data, experience, and lessons learned can be transferred and reused within the product development process.

In the next step, a gap analysis was conducted to identify integration aspects that are only partially addressed in the existing literature. The analysis focused on how quality objectives, quality planning methods, operational activities, and feedback mechanisms are linked to product development work. A system analysis was then used to structure the relationships between the main elements of quality planning and successive stages of product development. The results of these analyses formed the basis for developing a three-layer conceptual model covering the strategic, process, and operational levels.

In parallel, a set of integration criteria was derived from the model's main mechanisms. These criteria were not treated as generic maturity dimensions, but as assessment areas directly linked to the organisational cascading of APQP-oriented quality planning. The six criteria are: Strategic approach, Quality methods, Knowledge flow, Cross-functional collaboration, Process control, and Customer integration. They were then used to construct the QPIMI maturity assessment matrix. The model and the matrix were refined iteratively by comparing the consistency of layer descriptions, relationships, criteria, and maturity levels. Redundancies were removed, and definitions were clarified to obtain a coherent framework for assessing the maturity of integration between quality planning and the product development process.

4. RESULTS

The proposed model (Fig. 1) represents the integration of quality planning with the product development process as a three-layer structure arranged within the APQP reference logic. APQP is treated as an established reference logic for product and process quality planning, while the model shows how APQP-oriented quality planning can be organisationally cascaded across strategic, process, and operational levels. The model links three main perspectives: the Product Development Process, Product and Process Quality Planning, and the Integration Interface between them. These elements are supported by Knowledge Management, understood as data analysis, data transfer, and knowledge reuse.

At the strategic level, the model covers the formulation of quality objectives and their alignment with product development goals. At the process level, it focuses on development stages, quality gates, process indicators, and coordination of quality planning activities. At the operational level, it refers to project tasks, quality feedback, problem-solving activities, and operational control. The downward arrows represent the cascading of requirements, while the upward arrows represent feedback and the transfer of implementation results. The right-hand side of the model groups strategic, process, and operational data used in product and process quality planning. The Integration Interface structures the links between both sides of the model through strategic alignment, process synchronisation and operational coordination. Quality planning methods such as Quality Function Deployment (QFD), Failure Mode and Effects Analysis (FMEA), Production Part Approval Process (PPAP), Statistical Process Control (SPC), Measurement Systems Analysis (MSA), the Eight Disciplines problem-solving method (8D), Poka-Yoke, the 5S workplace organisation method, and control plans should be understood as representative instruments rather than a closed or mandatory set. The Knowledge Management layer forms the foundation of the model. It supports the transfer of data, experience, standards, lessons learned, and good practices between organisational levels and between development projects. Its role is to ensure that quality planning is not limited to isolated project activities, but is supported by reusable organisational knowledge. The model, therefore, defines the main areas and relationships that should be integrated, but it does not by itself assess the maturity of this integration.

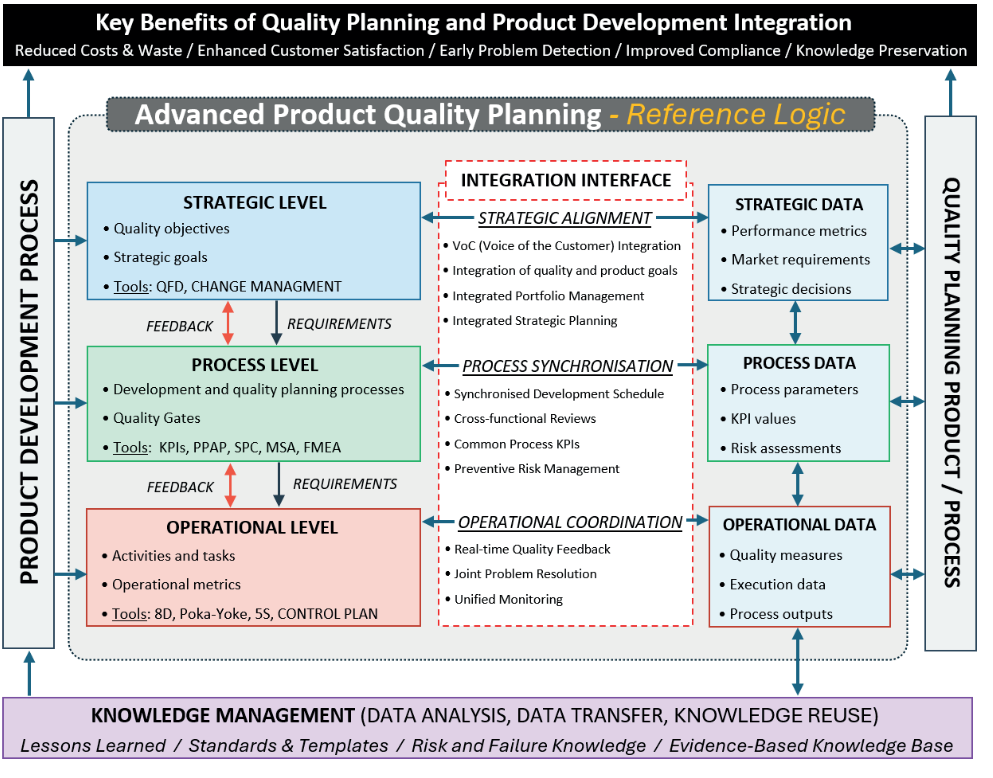

Fig. 1. *Model for integrating product development with product and process quality planning within the APQP reference logic*

For this reason, the model is complemented by the Quality Planning Integration Maturity Index (QPIMI), presented in Table 1. QPIMI translates the model's logic into a maturity-oriented assessment matrix. The matrix is based on six criteria: Strategic approach, Quality methods, Knowledge flow, Cross-functional collaboration, Process control, and Customer integration. Each criterion is assessed using five maturity levels: Basic, Proactive, Flexible, Progressive, and Sustained success. The scale reflects the transition from ad hoc, individually dependent practices to systematic, evidence-based and continuously improved quality planning. The detailed descriptors of the criteria and

Table 1. *Quality Planning Integration Maturity Index (QPIMI): six criteria across five maturity levels*

Integration criteria	Quality planning integration maturity levels (based on ISO 9004)				
	1. Basic level	2. Proactive	3. Flexible	4. Progressive	5. Sustained success
Strategic approach	Ad hoc	Project-oriented	Defined	Measured	Systemic
Quality methods	Non-standard	Partially standardised	Documented	Analytical	Automated
Knowledge flow	Personal	Databases	Structured	Analysed	Self-learning
Cross-functional collaboration	Informal	Defined	Systematic	Optimised	Anticipatory
Process control	Reactive	Basic	Criteria-based	Predictive	Self-improving
Customer integration	Reactive	Formal	Systematic	Predictive	Innovation-driven

The QPIMI result can be quantified by assigning numerical values from 1 to 5 to the maturity levels: Basic = 1, Proactive = 2, Flexible = 3, Progressive = 4, and Sustained success = 5. In the basic version, all six criteria are treated equally. This supports transparency, ease of interpretation, and comparability between assessment cycles. The global QPIMI value is calculated as the arithmetic mean of the six criterion scores:

$$QPIMI = \frac{1}{6}\sum_{i=1}^{6} s_i \tag{1}$$

where s_i denotes the score assigned to the i-th criterion. The QPIMI value, therefore, ranges from 1 to 5. A weighted average can also be used when justified by the organisational, project or customer context. In such cases, the weights should be defined and justified before the assessment is carried out.

In this article, QPIMI is understood as a structured, evidence-supported self-assessment rather than a fully objective measurement. To reduce subjectivity, the assessment should be performed by a cross-functional team and supported by observable practices and documented evidence. Such evidence may include, for example, APQP timing plans, FMEA records, control plans, validation plans, PPAP documentation, lessons learned databases, KPI dashboards, project gate reviews, customer requirement matrices, customer-specific requirement reviews, approval records and corrective action records. These examples should not be treated as a mandatory checklist, but as a basis for making the scoring process more transparent and repeatable.

Differences between scores assigned by individual participants may also provide useful diagnostic information. Large discrepancies may indicate that the process, responsibilities, or effects of integration are perceived differently by various organisational functions. In this sense, QPIMI supports not only the assessment of integration maturity but also the identification of areas requiring further clarification and improvement.

5. DISCUSSION

The Integration Model for Quality Planning and Product Development Process and the QPIMI matrix are conceptual in nature. Their role is to provide a structured framework for analysing how APQP-oriented quality planning is embedded in product development across the strategic, process, and operational levels. The contribution of the article is not the replacement of existing quality planning frameworks, but the development of a diagnostic perspective on how maturely such frameworks are cascaded, connected with organisational knowledge, and used in development practice.

The proposed approach should therefore be interpreted in relation to APQP, maturity models, and self-assessment frameworks. APQP remains the reference logic for planning, verifying, and approving product and process quality activities during development. QPIMI has a different role: it is a complementary diagnostic layer for assessing how APQP-oriented quality planning is deployed and used across organisational levels. This distinction is summarised in Table 2.

Table 2. *Comparison between APQP and QPIMI in the context of quality planning integration*

Aspect	APQP	QPIMI
Main role	Reference logic for product and process quality planning	Maturity-oriented assessment of organisational deployment of quality planning
Primary question addressed	What should be planned, verified and approved during product and process development?	How maturely is quality planning integrated across strategy, processes, operations, knowledge flow and cross-functional cooperation?

Table 2 (cont.)

Aspect	APQP	QPIMI
Main orientation	Project- and deliverable-oriented planning logic	Organisational integration and maturity assessment
Typical focus	Quality gates, deliverables, risk prevention, validation, customer requirements and process readiness	Strategic alignment, process synchronisation, operational coordination, knowledge reuse, process control and customer integration
Nature of use	Planning and execution framework	Diagnostic and improvement-supporting layer
Relationship between the approaches	Provides the reference structure for quality planning	Complements APQP by assessing the maturity of its organisational cascading and integration

This distinction is important because organisations may formally apply APQP, maintain required deliverables and pass project gate reviews, while still differing in the maturity of integration. These differences may concern the cascading of quality objectives, the use of evidence in decision-making, the transfer of quality-related data between project phases, the reuse of lessons learned, cross-functional collaboration, and the translation of customer requirements into operational actions. In this sense, QPIMI does not assess whether APQP exists in the organisation, but how mature APQP-oriented quality planning functions as an integrated organisational mechanism.

QPIMI has clearly defined operational boundaries. It does not replace APQP-based project planning, PPAP submission review, customer-specific approvals, project gate reviews, or technical document verification. It does not approve projects or confirm the technical correctness of quality planning documents. Its role is limited to diagnosing the maturity of integration between quality planning and product development across organisational levels.

In relation to broader maturity and self-assessment frameworks, QPIMI uses the general logic of structured self-assessment and maturity levels, but applies it to a narrower domain: the integration of product and process quality planning with product development. ISO 9004:2018, EFQM/RADAR, and general maturity models provide useful methodological foundations for improvement-oriented assessment. QPIMI translates this logic into a domain-specific structure focused on APQP-oriented quality planning, knowledge reuse, cross-functional collaboration, customer integration, and the operational use of quality-related evidence.

The proposed assessment approach still has important limitations. In its current form, QPIMI relies on structured self-assessment and expert interpretation of maturity level descriptions. Evidence-supported scoring can reduce subjectivity, but it does not eliminate it completely. For this reason, the QPIMI result should not be interpreted as a direct measure of business performance or project effectiveness. A higher QPIMI value may indicate better organisational conditions for quality planning, knowledge reuse, and cross-functional coordination, but it does not by itself prove lower costs, shorter lead times, fewer defects, or higher customer satisfaction. These relationships require separate empirical validation based on project performance data.

Future research should therefore focus on empirical validation of the model and the QPIMI matrix in organisations of different sizes and in product development environments with different levels of complexity. Further work should verify whether the proposed criteria and maturity levels are understandable for practitioners, whether they can be consistently supported by objective evidence, and which criteria are most useful for distinguishing different maturity profiles. Another relevant direction is the development of a hybrid assessment procedure combining cross-functional self-assessment with auditable evidence, quantitative indicators, and examples of good practice. In more digitalised environments, data analytics and process mining may also support the assessment by analysing digital traces of project activities, such as document changes, approval sequences, and review workflows.

6. SUMMARY

The article proposes a conceptual model for integrating quality planning with the product development process and introduces the QPIMI matrix as a maturity-oriented assessment structure. The main contribution is the organisation of APQP-oriented quality planning into a three-layer perspective covering the strategic, process, and operational levels. In this approach, QPIMI does not replace APQP, but supports the diagnosis of how mature quality planning logic is cascaded, embedded, and used within the organisation.

The proposed framework may support organisations in identifying weak areas of integration, especially in relation to quality objectives, quality methods, knowledge flow, cross-functional collaboration, process control, and customer integration. However, the study remains conceptual, and the QPIMI matrix requires empirical validation. Further research should verify whether the proposed criteria and maturity levels are understandable for practitioners, whether they can be supported by objective evidence, and whether changes in QPIMI results are related to project performance indicators such as time, cost, quality, and customer satisfaction.

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