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A SPECIFIC APPROACH ABOUT THE PROCESS MANAGEMENT IN THE AUTOMOTIVE INDUSTRY

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ABSTRACT: This study highlights the effectiveness of structured process modelling tools, including the SIPOC diagram and detailed process maps, in the field of automotive electronic component manufacturing, including ECUs. The detailed process map provides an extensive depiction of the production cycle, elaborating on the high-level overview of SIPOC. The diagram clarifies the interaction among many process categories: key operational flows, management oversight, and essential support activities including logistics and quality assurance. It underscores the vital role of integrated systems like the Manufacturing Execution System (MES), particularly its traceability and interlocking capabilities, which are critical for ensuring product conformity and real-time quality control in the stringent automotive sector. The capacity to analyse the diagram from many perspectives (automotive specs, SIPOC framework, and process flow) considerably improves its effectiveness for process analysis and improvement. The methodical application of process visualization tools, like SIPOC diagrams and detailed process maps, provides essential clarity and structure for managing the intricacies of automotive production. They provide a shared understanding, facilitating effective monitoring and regulation through systems like MES, maintain adherence to rigorous quality standards such as IATF 16949, and create a basis for targeted continuous improvement efforts.
KEYWORDS: Automotive manufacturing, SIPOC, Electronic Control Unit, processes management, Manufacturing Execution System

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1. INTRODUCTION

Traditionally, research in business process management (BPM) has focused on the design, analysis, monitoring, and improvement of business processes within businesses [1].
Researchers have developed ideas and strategies that address various aspects of BPM.
The life cycle model highlights that business process management is a continuous endeavor involving various stakeholders [2].

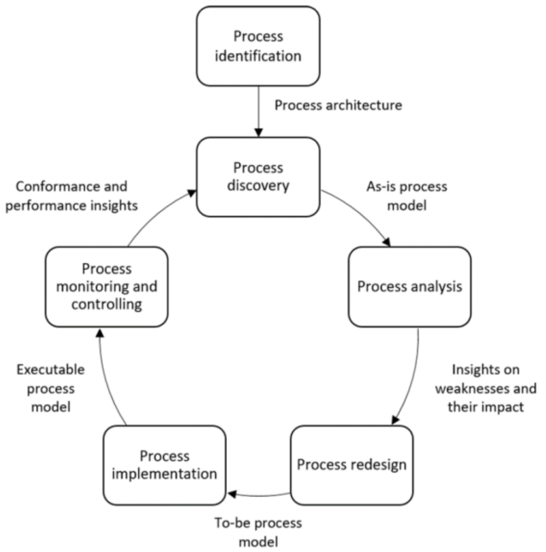

Figure 1. The Business Process Management life cycle [2]

Figure 1 depicts the six phases of the business process management life cycle. The life cycle starts with process identification.

During this phase, a BPM team delineates the specific business processes within an organization that require management, along with their boundaries. This initiative culminates in a process architecture that illustrates the primary processes and their interrelations. The BPM team establishes key performance metrics and objectives to enable the prioritization of processes and assessment of potential interventions. The standard performance metrics are cost, time, quality, and flexibility. This phase of the life cycle has mostly focused on the creation of models, methodologies, and systems for process architectures [3].

During the process discovery phase, a particular business process is delineated to establish a shared comprehension among the stakeholders on the execution of the activity. In BPM, this is referred to as an as-is model, as it delineates the process as it is presently executed. Data regarding the execution of the process is gathered by document analysis, interviews, and observation. This phase centers on process modelling, prompting research into the suitability of process modelling languages and the impact of various aspects on their comprehension [4].

The process analysis phase involves reviewing the process through the existing process model to identify issues, their origins, and their effects. The methodologies that facilitate this phase can be categorized into qualitative and quantitative. Qualitative techniques encompass, among others, value-added analysis, waste analysis, and root cause analysis. Quantitative analysis methodologies rely on simulation, flow time assessment, and queuing theory. Thereafter, possibilities for process enhancement are assessed during the process redesign phase. This phase aims to define and construct a prospective business process together with its associated process model. In contrast to an existing process model, a future process model illustrates the intended execution of a process moving forward. Numerous methodologies exist for business process improvement. The redesign orbit differentiates between transactional and transformative, internal and external, as well as creative and analytical methodologies [1].

Subsequently, during process implementation, the prospective process model is executed. The implementation is facilitated by change management and the development of IT applications for executing the future process. BPM research primarily focuses on the latter component, including methodologies and tools that facilitate the conversion of future models into software. Process-aware information systems are frequently utilized to facilitate process implementation and, thereafter, execution. These encompass, among others, enterprise resource planning systems and business process management systems, formally referred to as workflow systems [4].

The final phase of the life cycle is process monitoring and control. The objective of this phase is to comprehend the execution of the process and implement corrective measures if required. Performance tools can show process execution data, offering insights into critical metrics and process-related concerns [2].

Bizmanualz [5] maintains that the most straightforward and optimal definition of a method is "a documented process." However, this raises the question, "What constitutes a process?" When constructing procedures, clarity is essential for comprehension and adherence by individuals. It is essential that each of them be clearly specified.

ISO 9001:2015 defines a process as a series of interconnected operations that convert inputs into outputs. Inputs and outputs may be either tangible, including materials, equipment, or components, or intangible, encompassing energy, software, training, and similar elements. Outputs can be undesirable, such as waste. Every process involves customers and other stakeholders (both internal as well as external to the organization) who are influenced by the process and who determine the outputs based on their requirements and expectations [6].

Process effectiveness comprises the capacity to attain desired outcomes through the measurement and monitoring of a process's inputs and outputs, as illustrated in Figure 2.

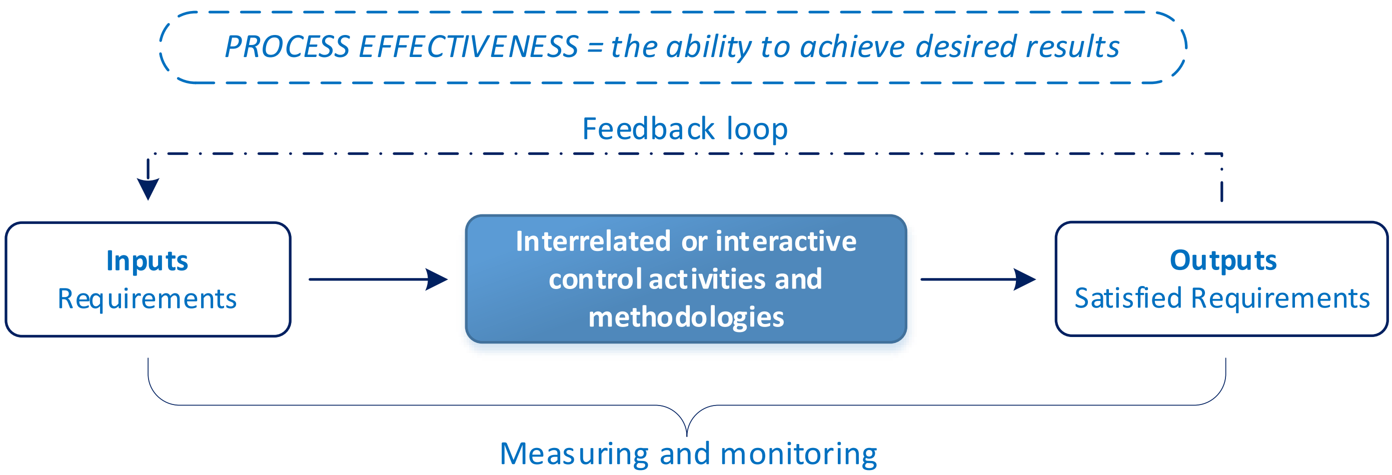

Figure 2. Process effectiveness [5]

With an emphasis on its multidimensional influence on operational efficiency, flexibility to changes in the external environment, and on the quality of education given, the authors investigate in [7] and [8], the strategic integration of quality management in libraries.

2. PROCESSES IN AUTOMOTIVE

The efficiency and efficacy of managing series production processes in the automobile industry are crucial, considering the sector's escalating demands for quality, speed, and adaptability.

Concurrent realization of product development and quality assurance is one well-known strategy to raise efficiency and effectiveness. This approach minimizes effects on ultimate output by addressing possible difficulties in the early phases of manufacturing, hence moving them upstream. Research of Kušar et al. indicates that the application of this approach can greatly increase industrial productivity inside automotive organisations since it helps to create more efficient manufacturing surroundings [9].

Moreover, agile approaches, originally formulated for software development, have gained recognition for its prospective advantages in the automotive industry. Venczel et al. [10] contend that these techniques increase flexibility and facilitate iterative enhancements, which are crucial for adapting to fast market fluctuations and customer requirements. The adaptability is additionally corroborated by Scharold et al., [11] who illustrate a good association between agile team maturity and key performance indicators in automotive development.

Quality management standards, like IATF 16949:2016, are essential for enhancing production processes. Gruszka and Misztal [12] assert that these standards impose rigorous criteria that necessitate organisations to enhance operational efficiency and adjust to market demands. The strategic integration of emerging technologies, such as the Internet of Things (IoT), is crucial for optimizing manufacturing processes and promoting innovation. Shah et al. explore the importance of innovation management in connected automobile systems [13].

Lean manufacturing methodologies have emerged as essential factors in augmenting operational efficiency through the systematic minimization of waste and the enhancement of value streams. Parker's assessment of lean principles in the automobile sector illustrates their considerable capacity to transform manufacturing processes by promoting creative development methodologies and inter-team communication [14].

The use of total quality management (TQM) systems is widely acknowledged as vital for sustaining competitive advantages in the automotive sector. Rosa et al. [15] indicate that TQM methods directly enhance the competitiveness of automotive components suppliers through an emphasis on continuous quality improvement and operational excellence.

Optimizing assembly procedures is critical in the automotive sector because they account for a significant share of total production costs. Ju and Pan [16] emphasize that assembly procedures can have a major impact on overall production efficiency, confirming the claim that targeted improvements in this area result in better resource use and cost reductions.

Overall, the introduction of these ideas and practices within the automotive industry indicates a determined attempt to improve both efficiency and effectiveness in serial production processes. As manufacturers implement more innovative ideas and adhere to stringent standards, the opportunity for improved operational metrics becomes clear.

Simple and effective process modeling tools, such as the SIPOC diagram and the process model, can be employed to establish a well-defined process.

SIPOC, an acronym for "Suppliers, Inputs, Process, Outputs, Customers," is an essential process mapping tool that significantly contributes to the manufacturing of electronic components in the automobile sector. SIPOC diagrams serve as a foundational tool in quality improvement initiatives by delineating the parameters of a process and identifying the essential components that require regulation. Clarity is crucial in automotive production, as high-reliability electronic components are incorporated into intricate vehicle systems, necessitating stringent quality control and process uniformity [17]. Figure 3 illustrates the SIPOC diagram utilized in the manufacturing of automotive electronic components.

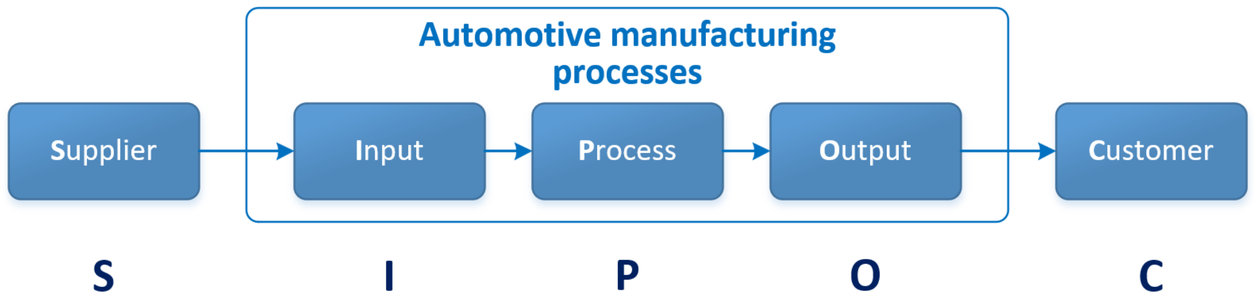

Figure 3. SIPOC in automotive manufacturing processes

In automotive electronic component production, the use of SIPOC is frequently combined with techniques like Lean Six Sigma and PDCA (Plan–Do–Check–Act) to facilitate continuous improvement.

Researchers have indicated that hybrid frameworks integrating SIPOC with Six Sigma's DMAIC (Define, Measure, Analyze, Improve, and Control) methodology markedly improve process performance by identifying essential process variables from suppliers to final customers [17][18].

Case studies in pertinent automotive sectors have shown that SIPOC utilization aids in the early detection of process inefficiencies and establishes a clear connection between upstream supplier inputs and the quality of the final output, which is crucial for ensuring that electronic components satisfy the rigorous standards of automotive applications [19].

Moreover, SIPOC's function in the manufacturing environment clarifies the Critical to Quality (CTQ) properties required for electronic components, thereby matching the production process with end-user expectations and safety criteria natural in the automobile sector. The visible mapping SIPOC offers helps to coordinate components testing and validation procedures, improves waste reduction, and underlines successful communication across cross-functional teams. Therefore, the methodical application of SIPOC not only improves process transparency but also helps initiatives for continual quality improvement in a very competitive and technologically demanding sector [19][20].

Another process modeling instrument is the Deming PDCA cycle. The Deming cycle, from figure 4, is readily applicable to process modeling, as it is inherently a process itself.

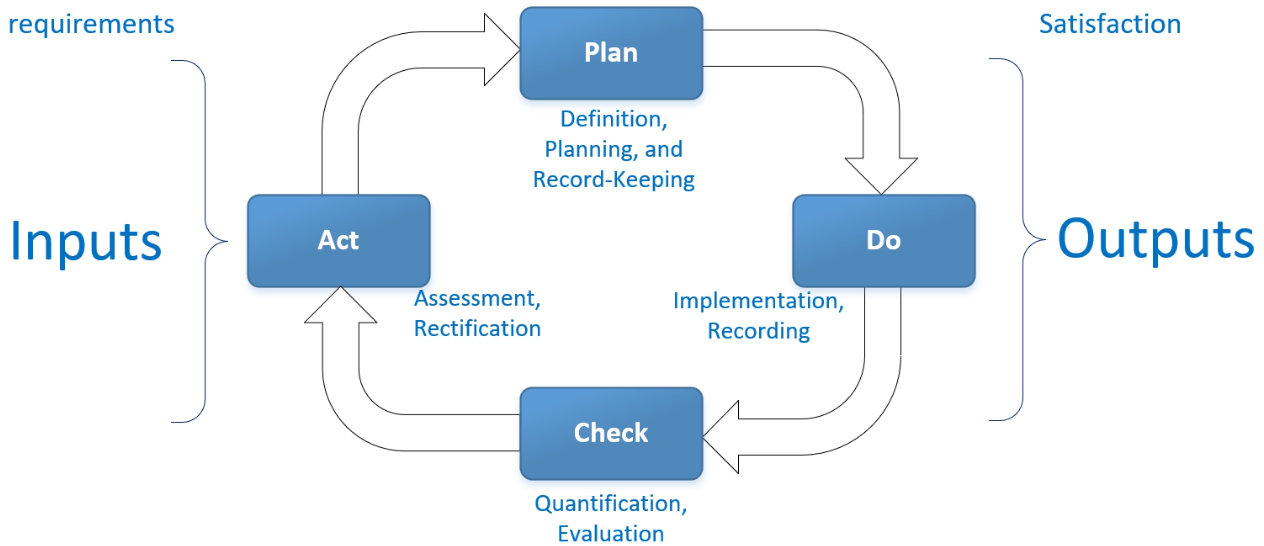

Figure 4. PDCA – process model

A well-defined process must answer questions concerning the Plan, Do, Check, Act technique, such as:

- Plan the process, establish the objectives (what the outcome should be), explain the various needs (customer, regulatory, standards-based, internal, etc.), and describe how it will get from point A to point B and back again;
- Do the process and gather information about it; The data element is crucial for providing feedback and determining whether the process is under control;
- Check the process by examining the obtained data and analysing its performance (not only against the specified objectives, but also for variability, consistency, and trends);
- Act to the review findings by either continuing the process as is or altering it to make it work better and implementing the revised procedure.

The PDCA cycle provides an excellent framework for establishing business operations. It is frequently utilized as a fundamental step for procedures. This process paradigm applies to any procedure, including manufacturing and human relation.

3. PROCESS MAP WITHIN AUTOMOTIVE PRODUCTION

The SIPOC diagram can be scaled up to encompass production processes within the automotive organization. Figure 5 depicts a systematic overview of a manufacturing process, typically for Electronic Control Unit gathering incorporating essential production processes with management, control, and support services. The central processes facilitate the operational continuity of manufacturing. The management processes oversee the central processes, while the basic processes offer support and services to them. The central processes constitute the production chain of the final product to be delivered to the client. With the assistance of supply chain management (basic process), the supplier provides raw materials for the component placement process (central process). Subsequently, the components are soldered into printed wiring boards, followed by component testing, software installation into the electronic components, functional and system electronic testing, packing, and finally the delivery of the products to the end customers, supported by logistics.

The Manufacturing Execution System (MES) process holds a position at the intersection of central and management processes. Traceability assesses the outcomes of fundamental operations and executes the "interlocking" procedure. The IT procedure is entirely automated.

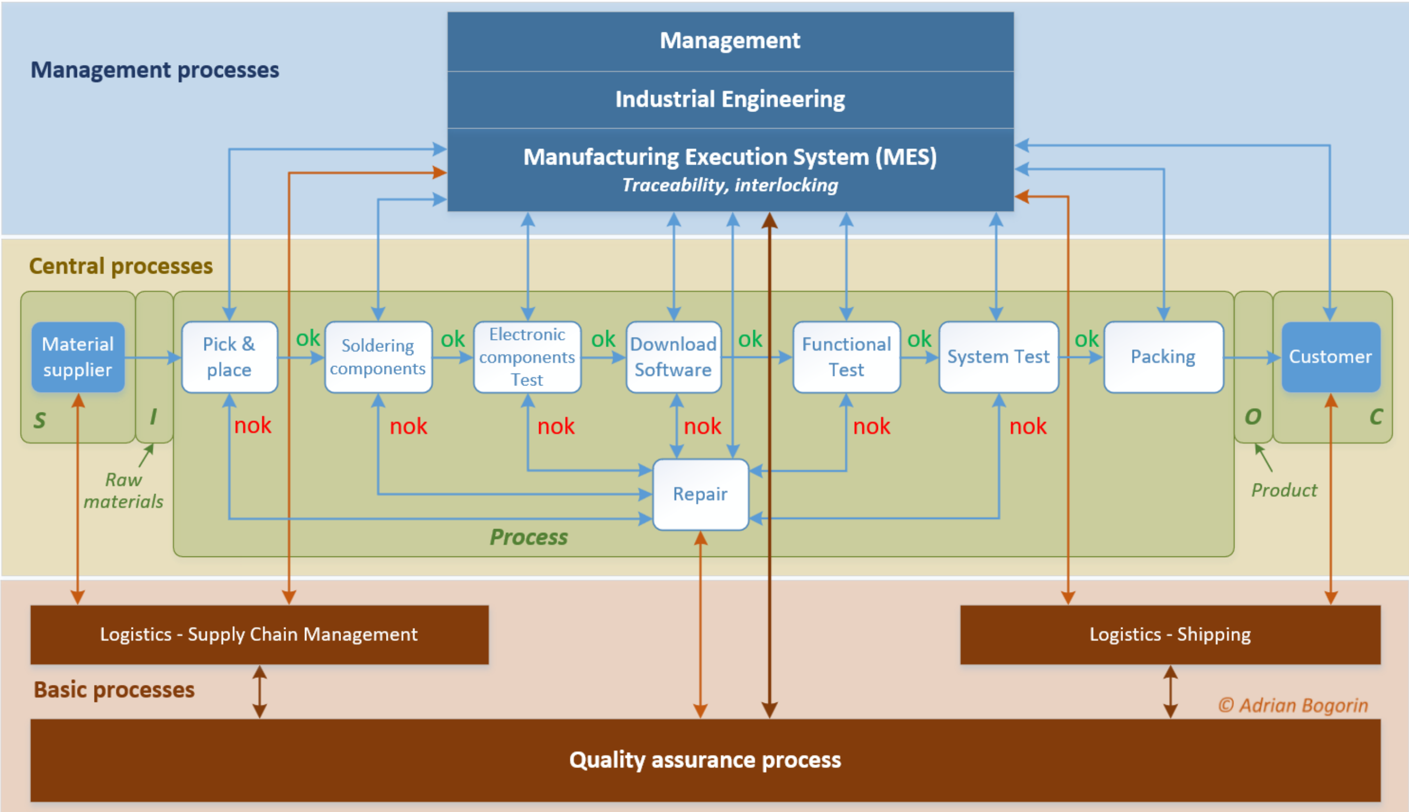

Figure 5. Three perspectives of manufacturing ECUs in automotive

The interlocking mechanism prevents non-conforming items from advancing to downstream process stations without prior analysis and necessary repairs. The traceability aspect includes evaluating both the quantitative and qualitative outcomes of product testing, as well as the distribution and stability of the tests. The quality process, as a basic process, has an inherent connection to the traceability process and directly governs the essential operations of supply chain management and logistics. The quality department holds the authority to halt production entirely when necessary, such as in cases of recurrent non-conforming goods or non-compliant raw materials. Traceability facilitates the collection of data pertinent to each specific process within the manufacturing flow. Furthermore, for the auditing of central operations, quality can directly extract data from the traceability process.

Figure 5 presents the production flux from three different points of view: Automotive Manufacturing Perspective, SIPOC Diagram Perspective, and Production Process Map Perspective.

3.1 Automotive Manufacturing Perspective

This process map closely matches the production flow usually used in the manufacturing of automotive electronic components, including Electronic Control Units (ECUs) and other modules. The implementation of a Manufacturing Execution System (MES) is crucial, as MES plays an essential role in the automotive sector for real-time management and data collection. The explicit reference to traceability and interlocking within the MES points out features that are vital in automotive production; these are crucial for complying with rigorous safety regulations, complying to quality standards such as IATF 16949, and facilitating accurate recall management when required. The diagram illustrates a comprehensive, multi-phase testing protocol, encompassing Electronic Components Test, Functional Test, and System Test, which signifies the automotive industry's requirement for exceptional reliability and performance validation. The process of downloading software is typical of contemporary automobile components that necessitate particular firmware installation during assembly. The existence of a specialized repair loop for units that fail testing ("nok") is a regular procedure in automotive manufacturing, intended for efficiently managing production yield and costs while maintaining rigorous quality control. The integration of MES, traceability, interlocking, and extensive testing is particularly suited to the demands of the automotive supply chain, although it may also be relevant to other electronic manufacturing sectors.

3.2 SIPOC Diagram Perspective

Figure 5 contains all essential components to serve as a comprehensive SIPOC (Suppliers, Inputs, Process, Outputs, Customers) diagram, utilized for high-level process mapping. The "Material supplier" clearly specifies the Suppliers, whereas "Raw materials" serve as the principal Inputs; nevertheless, software acquired during the process may also be regarded as an input. The core sequence of activities includes: Pick & place, Soldering components, Electronic components Test, Download Software, Functional Test, System Test, and Packing combined with the Repair loop defines the Process itself.

The result of this process is the completed "Product," which is provided to the distinctly recognized Customer. This diagram surpasses a conventional high-level SIPOC by defining the fundamental process into discrete steps and integrating specific quality checkpoints and decision pathways.

3.3 Production Process Map Perspective

Figure 5 functions as a production process map, illustrating the sequence of actions necessary for product manufacturing. It distinctly delineates the workflow, commencing with material inputs and advancing through stages such as Pick & Place, Soldering, Testing, Software Download, and Packing, and finally ending in delivery to the customer. The map features essential decision points denoted by the "ok" and "nok" (not okay) branches subsequent to test stages, which guide the product trajectory based on quality results. It also shows the rework trajectory via the "Repair" cycle for items that fail first quality assessments. This map's primary strength lies in its amalgamation of fundamental production phases ("Central processes") with advanced control systems like the MES in "Management processes," alongside vital support operations such as Logistics and Quality Assurance depicted in "Basic processes." The differentiated stratification facilitates the organization and differentiation of the strategic, operational, and support functions within the comprehensive manufacturing system.

4. CONCLUSIONS

The automotive industry functions under significant pressure to produce high-quality products efficiently and flexibly. This study emphasizes the critical importance of successfully controlling and optimizing series production operations. Although several tactics such as concurrent engineering, agile approaches, Lean, and TQM enhance performance, the essential initial step frequently involves the precise definition and visualization of the processes themselves. This study emphasized the efficacy of structured process modeling tools, particularly the SIPOC diagram and comprehensive process maps, in the realm of automotive electronic component manufacture, including ECUs.

The detailed process map offers a comprehensive picture of the production flow, expanding upon the high-level overview of SIPOC. Figure 5 exemplifies the sequential nature of intricate assembly operations, including component placement, soldering, various testing phases, and software installation. The map elucidates the interplay among many process categories: primary operational flows, management oversight, and fundamental support activities such as logistics and quality assurance. It highlights the essential function of integrated systems such as the Manufacturing Execution System (MES), especially its capabilities for traceability and interlocking, which are crucial for assuring product compliance and controlling quality in real-time within the rigorous automotive industry. The ability to examine the diagram from many viewpoints (automotive specifications, SIPOC framework, and process flow) significantly enhances its effectiveness for process analysis and enhancement.

The systematic use of process visualization tools, such as SIPOC diagrams and comprehensive process maps, offers crucial clarity and organization for navigating the complexity of automotive manufacturing. They promote a collective comprehension, enabling efficient oversight and regulation via systems like MES, uphold compliance with stringent quality standards like as IATF 16949, and establish a foundation for focused continuous improvement initiatives. Utilizing these approaches is not only advantageous but increasingly essential for manufacturers seeking to sustain competitiveness through improved efficiency, quality, and process control in the evolving automotive sector.

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