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Procedia CIRP 17 (2014) 32 – 37

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Variety Management in Manufacturing. Proceedings of the 47th CIRP Conference on Manufacturing Systems

Application of the stage gate model in production supporting quality management

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Abstract

Product and process quality was and still is a key factor of success for manufacturing companies in the competitive global business environment. The stage gate model represents a well-established method for quality management in the product development domain. This paper discusses the application of the stage gate model in the domain of production. The two domains differ in certain areas, which has to be reflected by the adapted stage gate model. The preliminary findings of the two case studies, covering manufacturing and assembly processes, indicate that an adapted stage gate model may provide valuable support for product and process quality improvement. However, the success is strongly dependent of the right adaptation, taking the individual requirements, limitations and boundaries into consideration.

Selection and peer-review under responsibility of the International Scientific Committee of "The 47th CIRP Conference on Manufacturing Systems" in the person of the Conference Chair Professor Hoda ElMaraghy"

Keywords: stage gate model; quality gates; manufacturing systems; product state; data capturing; quality management; relevant information

1. Introduction

Manufacturing systems are becoming increasingly complex and with this development the challenges towards information management increase. With each step along the manufacturing programme, the potential costs of quality problems namely rework or scrap increase. Today, the technological development, especially in sensor technology, allows for measuring a large amount of data during the manufacturing process. Common tools utilized in intelligent manufacturing systems like process monitoring, diagnostics and control, made large progress in order to handle quality problems. Most of those models rely on the availability of relevant information and data of the product state along the process at the right time (use of data). There is a lot of research available on when the relevant information must be available during a production process. However, determining the right time (capturing of data) within the process to capture the relevant information is not yet sufficiently discussed by industry and academia.

The stage gate model [1, 2] presents a well-established methodology to determine so called gates during a product and software development process, at which the state of a development process is matched against agreed parameters. In case the state does not match, the process cannot continue. Even though characteristics and requirements of production differ from product development, the question arises if applying such a model in that domain could be beneficial from a (product) quality perspective. Questions such as the ones listed below are analyzed in the following sections (see [Q1-Q4] in the text to navigate directly to related discussion):

- [Q1] Is the stage gate model transferable to the production / manufacturing domain?

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doi:10.1016/j.procir.2014.01.071

- [Q2] What are the potential benefits of applying this model in manufacturing?
- [Q3] Does the model have to be adapted and if yes, what has to be adapted and why?
- [Q4] What are challenges & limitations?

1.1. Structure of paper

The paper first presents the state of the art in information capturing in manufacturing with a focus on determination of the right timing, before introducing the stage gate model [1, 2]. The "suitability" of the stage gate model from the product development domain in production is elaborated based on a comparison of manufacturing processes and software/product development processes. Then, to preliminary evaluate the theoretical findings, two case studies, one from a SME with job-shop manufacturing and a second one from a clocked assembly line at an automotive OEM, will be presented with an application of the model. A critical discussion will conclude the preliminary findings, followed by an outlook on future research.

2. Background

In this section, after briefly establishing the perspective on information capturing as a basis for the further discussion within this paper and introducing the original stage gate model from the product development domain, a comparison of production and development processes is presented. The findings of this comparison are the basis for the later application of a product development support method, the stage gate model, in a production environment.

2.1. Information capturing in manufacturing

From an item-level Product Lifecycle Management (PLM) perspective it is necessary to link the captured information to a specific object. Therefore, the object has to be identified precisely and uniquely. The identification can take place automatically by e.g., scanning a barcode or a RFID transponder or by entering the information manually into an IT system etc. Another critical element of information captured is time. A time stamp integrated into every event captured is necessary for having unique information. Moreover, the time stamp is necessary to have a precise history of every object being tracked within the supply chain. Knowing about the location of an object is also very important when generating an event, e.g. information of the current process can be derived based on location/time. Last but not least, the product state, which incorporates various characteristics of a product e.g., quality, dimensions, etc. of an object is considered relevant information. Based on the product state's characteristics, the following process steps and their parameters within supply chains can be planned. An example for a state characteristic is the diameter after machining, but also residual stress allocation within a steel disc [3]. In this context, the question of the time horizon of information capturing comes up. As stated before, the information and data has to be captured in real time, which is understood within this work as available when needed.

2.2. Stage gate model

The stage gate model with its deployment of quality gates is applied primarily in product development processes. The first occurrence was in the software development domain [4]. The development of complex products often carried out over a period of several years, leads to significant challenges when it comes to coordination and synchronization. It is elementary to agree on a reference process, which guides the development teams through the process. The development tasks are structured in consecutive process phases based on the reference process and distinguished by quality gates as a monitor and control tool [5]. The basic idea of the stage gate model is to divide a process in different phases and create a quality gate at critical points in order to secure that the targeted goals are reached before proceeding to the next process phase [6]. The quality gates represent decision points, which determine on the basis of the current status of the process if the project is continued, adapted/revised or terminated [7]. The development process cannot pass a gate when it does not meet all set criteria [1].

The phases of a product development process are difficult to plan, especially the early ones often inheriting creative parts and parts without clearly defined goals. For these phases, the stage gate model offers the advantage to create a monitoring and control mechanism without set in stone timeframes and the needed flexibility solely based on the state of the project [8]. The method is especially useful when the successful launch of a (later) process phase depends on the fulfillment of all requirements by previous processes [2, 6].

Today the stage gate model is applied in practice in various industries supporting product development processes. In the automotive industry, BMW, Audi, General Motors and Daimler are examples of companies successfully implementing the stage gate model. In practical application different variations of the term stage gate were established. It was Daimler who introduced the most well known variation naming the gates 'quality gates' [5].

Even though quality gates share various characteristics with milestones, quality gates and milestones are not the same. Quality gates determine distinct checkpoints where specifically defined requirements are reviewed in a coordinated effort between process customer and process supplier. The accomplished results needed and how they have to be measured (e.g., through Key Performance Indicators (KPIs)) are described in detail in the checklists for the quality gates. For milestones it is not necessary to define specific KPIs. Milestones incorporate mainly the definition of target dates for the accomplishment of certain targets. A milestone can therefore be 'passed' without reaching the defined target, whereas that is not possible for a quality gate [6]. For quality gates, result oriented product and process specific content and performance has to be defined and monitored [9].

The goal of quality gates is the improvement of process quality and thereby ultimately of the final product quality through monitoring and control of the product development