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Production System change strategy in lightweight manufacturing

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Abstract

Two change management strategies: a minimum change, exploitation strategy (kaizen) and a maximum output, exploration strategy (kaikaku) have been applied in a manufacturing case study. Value stream mapping and discrete event simulation were used to analyse the production system changes, with regards to robustness and total lead-time, to increase knowledge of how to choose change management strategy. The results point out that available time is crucial. It is important to consider not only product specification and return of investment, but also the change and risk management. Future research should develop engineering change management further.

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Keywords: Engineering Change Management; exploitation; exploration; Kaikaku; Change management strategy

1. Introduction

When companies need to do process and product changes, two mental approaches comes in an engineer's mind: the first is ”change as little as possible, improve in many small steps” the other approach is ”take a large step, and include as many improvements as possible”. The wanted output for the first exploitation-based approach is continuous improvements (kaizen) i.e. predictable controlled changes that may be reversed if they don't have the desired outcome. The second approach, however, is more explorative and aims at radical and innovative improvements (kaikaku).

In kaizen, or continuous improvements (CI), is control kept at team level and management focus on coaching improvements in a so called “Kata” process [1]. In order to create alignment, improvement challenges toward a vision target state are given, and actions are made as stepwise experiments toward that vision target state. Target states should not have a single numerical goal [1,2], rather several targets or performance measures are monitored in order to know if the target state is satisfied [1]. Teams should document 'next target state', expected result, the actual result and the learning's for each experiment to define the 'next target state' towards the vision [3].

The radical improvement process, or kaikaku, however, is characterised by creativity and innovation to reach the target state, thus being concordant to exploration strategy [4, 5]. Exploration implies experimentation, a high novelty of the ideas generated, variation, deliberate risk-taking, free association, diversification and ample choice. Consequently, kaikaku significantly differs from kaizen/CI from a methodological standpoint, as kaizen instead corresponds to exploitation strategy, implying control, stability, reliability, refinement, minimal deviation, convergence and repetition.

In manufacturing there are several occasions when there are internal improvement needs, such as shorten lead-time or increase productivity, by doing process changes (e.g. reduce setup times) or product changes (e.g. change joining). But there may also be external, customer induced changes (e.g. shortening of lead-time or change of product properties). One example of a complex manufacturing process with internal and external requirements is injection moulding. Injection moulding (IM) with subsequent lamination is used for manufacturing of several types of automotive components. Due to high pressure, the IM-machines are heavy and hard to

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handle manually, with the consequence that e.g. setup-times often becomes long. Set-ups include lifting, changing and cleaning tools/moulding dies, adjusting and trial runs. The changeover may typically take several hours [6]. The operation involve four stages to form the product out of plastic pellets; plasticization, injection, packing and cooling [7], with hydraulic and screw systems used in combination to press the plastic in the mould. The process stability and overall equipment efficiency are affected by the operator´s experience, the design of parts and moulds and the plastic raw material characteristics. Increased knowledge regarding process parameter settings and adjustments is an important improvement factor. Since lamination and injection moulding equipment are large and expensive there is an important question of how to handle risk and management control in both the management strategies.

Although the extensive literature on kaizen/CI through the lean tradition, as well as more emerging literature on radical improvement, there is a lack of empirical studies of the link between chosen improvement strategy (radical or incremental) and the required strategy analysis (especially considering risk and verification analysis).

In order to address this identified research gap, a single case study was conducted involving a manufacturing process of a plastic component for vehicles where there is a customer demand to change to a lighter material and an internal factory demand to shorten lead-time and increase capacity and productivity. The specific research question for the case study was formulated as: *What are the management consequences of the choice of improvement strategy (radical or incremental improvement strategy)?* The case analysed two improvement scenarios, one radical improvement and one incremental improvement, and related those to the needs of analysis tools and strategies.

The situation described in this case study is common in automotive industry, where there are many similar situations in manufacturing industries when internal and external demands induce product and/or process changes and there is a managerial need to choose improvement change strategy. This case study is used to present the management dilemma and reasons to go in either strategic direction.

The paper presents the concepts of incremental improvement strategies like continuous improvements-kaizen and of radical improvement strategies kaikaku. These two have been compared in an early concept case study where engineering change management (ECM) has been used as structure for the case study investigation. Literature best practice data has been used as input, and then value stream mapping and discrete event simulation has been used as analysis tools in the comparison.

2. Theoretical background

There is an extensive body of literature and practice established for incremental improvements (kaizen/CI) in manufacturing. Using lean tools like SMED (single minute exchange of dye) often give improvements in reduced setup times. Although some early cases report more than 95% improvements [8], reductions in changeover time of between 50% and 75% is regularly reported [9,10]. Similarly if teams focus on unplanned machine stops, condition based maintenance and operator driven maintenance (autonomous maintenance) may reduce unplanned machine stops by 50-75% [11]. In injection moulding, SMED empowered with Taguchi parameter setting, may give improvements of at least 50% [7]. In addition simultaneously setup time reductions may improve maintenance and thus downtime due to maintenance [10]. In the case study, the easy improvement opportunities have already become exhausted, so the lower end of improvements are expected in the incremental improvement scenario. However if SMED knowledge is incorporated in machine design (as in the exploration scenario) a very high rate of improvement can be expected [12].

Radical improvement such as kaikaku is characterized by episodic occurrence and fundamental change. It is a process that intends dramatic redesign of existing processes. The expected end results are often expressed in terms of 30 – 50 % performance increase of important parameters [4, 13]. However, as the specific improvement is based on current status, process maturity, and the choice of parameter(s), thus being highly contextual, these measures should be used as input for target setting rather than decisive success criteria of the improvement conducted [13]. Contrary to operator driven continuous improvements, kaikaku is often a top-down driven design process and the tools used involve change of product or process design or change of concept.

Drawing on the broad definition of engineering change management, ECM, by Hamraz, Caldwell, and Clarkson (2013);"ECs are changes and/or modifications to released structure, behaviour, function, or the relations between functions and behaviour, or behaviour and structure of a technical artefact."[14], the component design change in this case certainly lends itself to ECM processes. However, also subsequent change to the manufacturing system in this case can be described as an implicit change as opposed to explicit [15] and may be included in the definition. It is important to make a distinction between emergent changes and initiated change [16]. In our case change of component material is planned for, initiated. However, the processes to resolve the change is the same for both emergent and initiated (as in [16]), which would imply that the ECM process would be similar for implicit vs. explicit [15].

In the six steps engineering change process developed by Jarratt, Clarkson, and Eckert [17] that is applicable to changes be they implicit, explicit, emergent or initiated follow the structure:

1. Engineering change request raised
2. Possible solutions identification
3. Risk assessment
4. Selection of solution
5. Implementation of solution
6. Review of solution

ECM as a research discipline does not give any guidance over when to use incremental or radical changes. That being said, if a radical change is chosen, the six steps [17] above