# Using Differing Classification Methodologies to Identify a Full Compliment of Potential Changeover Improvement Opportunities

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**Abstract.** In recent decades industry has focussed a lot of attention on changeover performance, recognising it has to reduce changeover losses in multi-product manufacturing environments in order to remain competitive.

This paper seeks to analyse the complexity of the changeover problem and the scope of the diverse improvement opportunities which typically are present. It does so by investigating widely variable changeover classification methodologies which have been developed to date. The paper discusses how suitable elements of these existing methodologies might be combined, thereby guiding the changeover practitioner in a structured fashion to consider a full compliment of potential improvements.

**Keywords.** Changeover classification, changeover improvement framework, changeover improvement rules

## 1 Introduction

From the end of the 1970's and into the 1980's and beyond, western volume manufacturers were confronted with an ever worsening competitive position relative, particularly, to leading Japanese manufacturers [1]. With the emergence of new manufacturing paradigms such as *lean* and *mass customisation* awareness has grown that competitive criteria extend considerably beyond those simply of high product quality and low unit cost which traditionally dominated in *mass production* [2]. A leading changeover capability greatly assists manufacturers to be more responsive and is widely identified to be at the heart of modern small-lot multi-product manufacturing practice [3].

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### 1.1 Changeover complexity and the use of indices

Changeover is assessed within the current paper as a complex, multi-dimensional activity, wherein very many opportunities are potentially available to improve how changeovers are completed. Notwithstanding the availability of various improvement methodologies, most notably the SMED (Single Minute Exchange of Die) methodology [4], changeover of equipment to enable the manufacture of a new product is in many circumstances both difficult and time consuming.

Whereas there are many different ways that complexity might be observed, complexity is usually only measured in practice in terms of time and, perhaps, the number of personnel employed. In both instances complexity is assessed by assigning indices to changeover activity, determining performance according to predetermined criteria (here, a simple time index and a personnel count index). Consequently improvement is often crudely sought only in these terms, where other performance indices are rarely pursued. Moreover, normally only internal time is measured, rather than the total time required to complete all tasks, including those which are concluded externally [4].

That other indices can be very beneficially employed is apparent in the early results of applying the University of Bath's Design for Changeover (DfC) tool [5-6], which seeks to guide the way OEM design in particular might be undertaken, and to determine what its impact might be. DfC particularly concentrates upon indicators of machine design complexity, and targets changeover improvement by redesign which will alter appropriate design-based indices.

## 2 Different classifications give different improvement awareness

Elsewhere [7] the authors have described the dominance of the SMED methodology and in turn the dominance when using it of pursuing organisation-led improvement. The authors further argue [7-8] that this situation is a reflection of the prominence of the prime objective of Shingo's methodology – of seeking to externalise changeover tasks – in the mind of those employing it [9]. If improvement is only sought by externalising tasks then those tasks will normally remain exactly as before (only being undertaken at a different time). The total amount of work which has to be completed logically remains the same.

### 2.1 Seeking a wider perspective of potential improvement opportunities

The premise above is that the prominent classification within SMED of a changeover comprising internal and external tasks substantially guides what improvement options are pursued. If so, alternative changeover classifications may cast new light on where gains can be found.

### 2.2 Classifications employed in changeover research at the University of Bath

The University of Bath has supported an extensive changeover research program for more than 15 years. In this time well in excess of 100 industrial partners have become involved in the research, based throughout the UK and mainland Europe. Many highly diverse industrial situations have been investigated.

The difficulty of understanding changeover in all its complexity and understanding all the myriad potential improvement opportunities which can be available is reflected in the number of classifications University researchers alone have adopted. Many of these classifications have been modeled from others' work, sometimes being adopted unchanged. Conversely some novel working classifications have also been developed.

Recognizing that an overall changeover is typically interwoven with aspects of technical, personnel and behavioral issues (both in the immediate confines of the tasks being undertaken and beyond) the paper now investigates some selected key global classifications – which are later collated together into a new improvement framework.

### 2.3 Organization and design

For many years University researchers have drawn a distinction between design-led and organization-led improvement [8]. Any chosen improvement lies on a spectrum between being 100% design based and 100% organization based (where only what people do is altered). Whereas retrospective improvement can be undertaken with either a design or an organizational bias, OEMs (Original Equipment Manufacturers) can only realistically pursue better equipment design. For such personnel in particular the University team has been developing its DfC tool.

### 2.4 Changing when tasks occur and changing what tasks occur

The authors have explained that a useful alternative perspective of changeover improvement to that of SMED is to recognize that individual tasks can either be conducted at an alternative time, or tasks can be revised such that the same tasks as before are no longer conducted [10].

In seeking to alter when tasks can occur the authors' approach is to seek improved allocation between the tasks and the resources necessary to complete those tasks. No distinction is made between 'separating' and 'converting' when tasks can occur [4], noting as well that useful improvement can often still be found even when tasks are not externalized [10].

### 2.5 The 4P's

Illustrated by figure 1, the separate 'P's' of People, Practice, Processes and Products have each been identified as a global influence on changeover activities and hence on measured changeover performance [5]. They are all available to be amended to support the required goal of faster and higher quality changeovers.

Hence, to gain improvement, the motivation of people might be addressed, or better training provided. Or the work practices which are adopted might be revised. Similarly, the products themselves might be redesigned to enable better changeovers, and physical revision to process hardware can be contemplated.

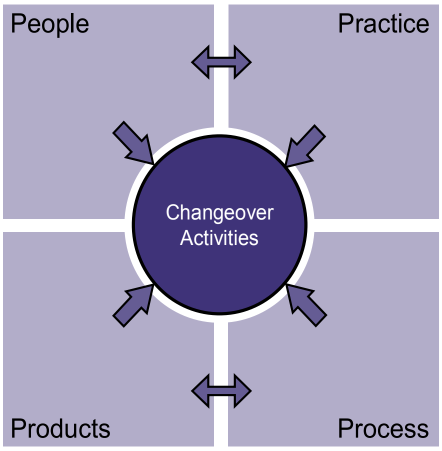


**Figure 1.** The '4-P' influences on changeover activities [5]

## 3 Discussion: diverse improvement opportunities

The desirability of enhancing manufacturing capability in changeover terms in the context of an environment of constant uncertainty and constant change is widely described [11]. Alongside better organisation of a changeover, as championed in many improvement programs, both product design and manufacturing process design also potentially have a key role to play [8,12]. Each presents opportunities to more rapidly and precisely adapt production processes for the manufacture of an alternative product. Reik *et al*. [5-6] describe specifically how better design can enable fewer, faster, simpler changeover tasks to be completed, yielding sustainable gains and significantly contributing to lean and competitive processes.

Whether by concentrating on design or concentrating on better organization, a generic approach to improvement can be proposed which is informed by the foregoing classifications. As will be further discussed, the approach is to seek one or both of a reduction in changeover complexity and change as to when tasks are conducted. Reducing variability (seeking standardization) represents one specific way that complexity can be reduced and is deliberately isolated in the proposed improvement framework as a sub-set of complexity reduction.

### 3.1 Reducing complexity

Whether seen as a series of tasks, activities, events or actions (or any other similar terms), all changeovers take a time to complete and represent a level of complexity. Reducing complexity by reducing the difficulty of individual tasks (or activities or events or actions) and/or their number should result in an easier and more rapid changeover being completed. Organizational and design-led approaches may both be employed. Complexity can be determined by whatever indices might locally be deemed appropriate, including combining them as ratios. Some very simple indices might be the number of hand tools used, the number of change parts or the distance that an operative moves.

### 3.2 Reducing variability (a sub-set of reducing complexity)

Improvement opportunities which include enhancing maintenance [13], repeatable good communication [14] and the adoption of best-practice standard procedures [15] have been reported in the literature.

These opportunities are all concerned with variability, which can add significant complexity to a changeover by necessitating non-standard tasks or procedures to be conducted (over and above the most efficient procedure possible within the constraint of given product and manufacturing process designs). It may be impossible to predict what these unnecessary additional tasks are as the changeover starts, and variability can sensibly be seen in its own right to be a major contributor to lengthy and inconsistent changeovers [16]. For example in the authors' experience, and supported in the literature [13], the condition of change items can often be critical. The need is for these change items all to be in a repeatable, known, standard condition. For example replacement ink in a print changeover requires to be mixed to the right color – if it is not then many iterative (and often highly time-consuming) adjustment or compensatory steps may have to be undertaken, usually whilst the production facility remains static [8].

Variability does not only relate to physical entities: human performance in particular is also likely to be important [16].

### 3.3 Changing when tasks occur

Importantly, despite the scope of the above options, it needs to be recognized that reducing complexity *per se* (including doing so by reducing variety) is not the only potential way that quicker changeovers may ensue.

An alternative strategy in many industrial circumstances is to change when tasks occur [10] – for example externalizing them, prior to production being halted [4]. The time at which tasks commence is changed, rather than the tasks themselves intrinsically being changed.

Changing when tasks take place has been argued elsewhere [10] to be strongly influenced to the ability to match tasks to the resources needed to complete them, most notably labor (which is the reason externalizing tasks is often particularly attractive). In other words task re-sequencing is potentially possible if a resource is not being used at any given time. Normally the task start time would be altered to minimize the period when production is interrupted by the changeover ('internal time' in SMED nomenclature).

Conversely, better matching of resources to the tasks which need to be completed can also be beneficial, for example adding more skilled labor or providing pre-setting jigs [10]. Once more the effect is potentially to allow change to the time when tasks can be undertaken, hence again reducing production losses.

## 4 Unravelling opportunities: a new framework

Illustrated by figure 1, the ‘4P’s’ of People, Practice, Processes and Products are each influential on changeover performance. They are all available to be amended to support the required goal of faster and higher quality changeovers. Standing alone however, the 4P categorisation still provides little detailed guidance as to how improvement might be undertaken. This situation changes when other perspectives are brought to bear, and more particularly if some sufficiently focussed working rules (or improvement directives) can be structured as a clear part of this fuller view. A candidate framework is presented as figure 2, which combines elements of the classifications previously outlined in section 3 with the generic approach discussed in section 4. Figure 3 articulates simple yet searching high level questions to be used within the proposed framework – outlining improvement opportunities in a similar manner to that done for example by DFMA (Design for Manufacture and Assembly) methodologies [17].

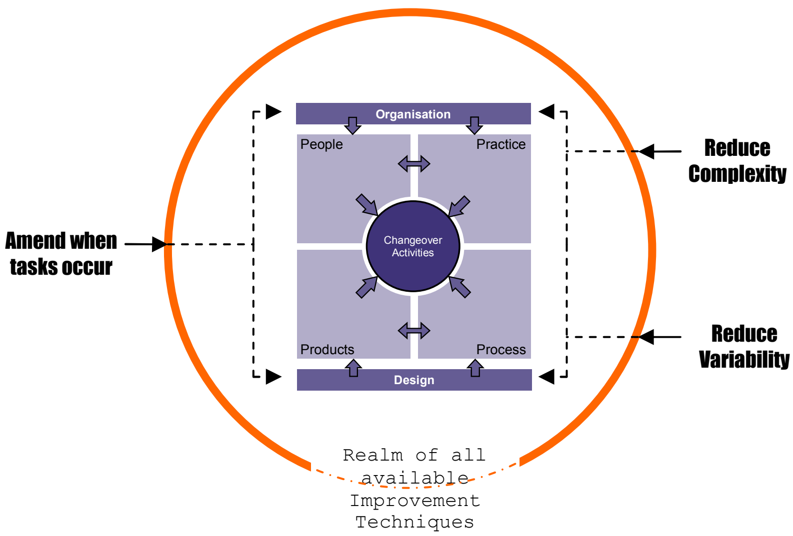


**Figure 2.** Integrating classifications (part 1): an improvement framework

Thus, first considering figure 2, a global objective of reducing complexity might be pursued. This objective might be pursued by using any relevant improvement technique, such as (but not limited by) those described by Shingo [4], where the chosen technique can be either organization-biased or design-biased [8]. The two rules which guide a focus on complexity, shown in figure 3, are those which respectively seek a reduction in any sensible locally defined activity count index and/or reduction in any sensible activity difficulty index – where a net reduction is sought across all the complexity indices which are being employed.

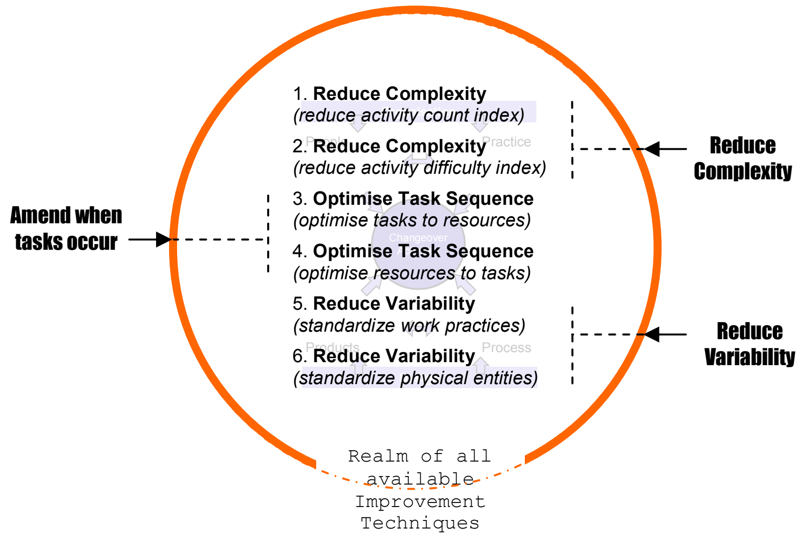


**Figure 3.** Integrating classifications (part 2): working rules for improvement

Similarly, amending when tasks occur – for which once again any relevant techniques can be used, with either an organization or design emphasis – involves better matching tasks to resources and/or better matching resources to tasks [10]. A design-led opportunity might be to provide specialist jigs and an organization-led opportunity might be to provide additional manpower. It is being sought in either case to optimize the task sequence and thereby reduce production downtime. A particularly potent technique can be that of externalizing tasks.

The final option of variability reduction equally guides improvement by use of any potentially relevant technique, once again with either an organization or a design bias. Variability of work practices relates to what people do. Variability of entities relates to physical hardware entities such as change parts, physical product entities such as surface finish and operational entities such as temperature.

## 5 Conclusions

Flexibility and responsiveness are watchwords of modern manufacturing, driven by a desire to reduce non-value-added activity and better respond to customer demands. Rapid changeover between products is paramount if genuine manufacturing flexibility and efficiency are to be achieved.

To date the quest for better changeover performance has been substantially guided by the pioneering work of the late Japanese engineer-consultant, Dr Shigeo Shingo. However it is becoming clear that his SMED methodology does not readily embrace all potential improvement opportunities, not least those which are available to an OEM (who in any case will realistically never be involved in retrospective improvement programs for which the methodology is intended).

This paper discusses how suitable elements of disparate classifications employed at the University of Bath alone during the past 15 years can usefully be combined, obliging a changeover practitioner to consider a full compliment of potential improvement possibilities in a much more structured fashion than hitherto. The proposed framework is applicable to all potential improvement opportunities where, dependent on the specific situation, some will be favored above others. It is applicable across all of a changeover's phases, including the run-up phase, once production has been restarted but has yet to stabilize.

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