The Role of Goal-Setting and Commitment in Continuous Improvement Processes

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ABSTRACT

One obstacle in the way of enduring process improvement is the necessity to gain and sustain a momentum towards change in organizations. Building upon previous work in the field of operations management and system dynamics, a generic model is outlined that mimics the implementation of several process improvement programs in an industrial organization. For this purpose, the model exhibits a conceptual distinction between particular improvement programs (e.g., total quality management, total productive maintenance) and the overall improvement process. The latter is represented by a continuous PDCA-cycle that connects organizational capabilities on process improvement, development of commitment towards change on different hierarchical levels, and managerial improvement goals with several improvement programs. Among other findings, the simulation experiments show that goal-setting is a crucial aspect in continuous process improvement processes that—if wrongly applied—can stall the organizational commitment to change. Furthermore analyses reveal that plants should strive for process improvement patterns that exhibit higher organizational rather than technical complexity. The value of the conducted approach lies in the explicit analysis of the interplay between goal-setting, organizational learning, program commitment, and process improvement programs.

DYNAMICS AND COMPLEXITY IN CONTINUOUS PROCESS IMPROVEMENT

The necessity to continuous change is an undisputed premise for economical success in most industries (Hahn, 2006; Doppler and Lauterburg, 2005). In the face of changing economic factors, process improvement programs therefore form rather the rule as the exception in the 'daily businesses' of enterprises. The manufacturing industry makes no exception to that. Rather the opposite is the case: a high variety of process improvement programs in manufacturing are accompanied by the paradigm shift in strategic management that acknowledges an important strategic role of manufacturing for the competitive position of a firm and its long-term success (Filippini et al., 2001; Zäpfel, 2000; De Meyer and Ferdows, 1990; Wheelwright and Hayes, 1985; Skinner, 1985, 1969). With their origins in manufacturing and in particular the automotive industry, many process improvement programs—like total quality management (Shiba et al., 1993)—are nowadays applied within quite different industries like healthcare and the service sector respectively (Slack et al., 2004). The industrial manufacturing sector is therefore locus of innovation and proving grounds for process improvement programs. Findings about the implementation of process improvement programs in industrial manufacturing are also prototypical for other industries (Größler, 2007).

Also in view of the necessity and ubiquity of change in enterprises very little can be stated about the success of improvement programs. This becomes apparent if one considers the success rates of process improvement programs. The success rates are between 20 and 50 percent albeit the fact that enterprises allocate considerable resources to their process improvement programs (Kotter, 2007; Strebel, 1996; Hammer and Champy, 1994; *The Economist* 1992). From a managerial point of view these results are quite depressing, in particular when faced with some enterprises that demonstrate to be outstanding successful in terms of process improvement (Easton and Jarrell, 1998; Shingo, 1993; Ohno, 1988). Yet, enterprises annually spend billions of Euros trying to duplicate those best practices but with limited success (Pfeffer and Sutton, 2000). The reasons for the low success rates indicated in the literature are quite diverse: they include lacking visible improvement results (Schaffer and Thomson, 1992), setting of wrong improvement goals (Beer *et al.*, 1990), insufficient commitment to a program or change respectively (Lines, 2004; Beer, 2003), and resistance to change *per se* (Strebel, 1996). They share, however, in the same way common characteristics:

1. All approaches are commonly stressing the importance of *soft* factors, like ‘perceived results’, ‘motivation’ and ‘commitment’. As soon as people with their expectations, emotions, and peculiarities are in the game, a great meaning is attached to soft and qualitative factors respectively in the literature (Cohen, 2003; Neubert and Cady, 2001; Meyer and Allen, 1997). From the importance of qualitative and hardly quantifiable factors for the success of improvement programs challenges arise for both researchers and corporate leaders: “the assets that really count are the ones the accountants cannot count” (Stewart, 1995: 91). One crucial aspect hence lies in the management of those qualitative factors in order to generate a momentum towards change in an organization.

2. In addition, the implementation of process improvement programs is characterized by a high variety and connectivity of elements of a corporate system (Milling, 1981). In industrial manufacturing, a great number of elements of an enterprise system are interacting with each other, for example, the management is interacting with the workers, and the workers are interacting with their machinery, manufacturing processes, et cetera. In general, in the social sciences we always are dealing with a tangle of relationships, in which we can easily lose the thread that guides us from causes to effects (Schumpeter, 1949). Thus, intended effects always go along with ‘side’-effects that are not anticipated by the actors in socio-economic systems (Sterman,

2001, 1994; Milling, 1991; Watzlawick, 1985; Forrester, 1975). It is one conclusion of Forrester that social systems are inherently insensitive to most policy changes that people select in an effort to alter the behavior of the system, and that our experiences, which have been developed from simple systems, lead us to look close to the wrong locations, where the low leverage points are located (Forrester, 1971). In the face of the importance of qualitative factors as well as the complexity of a system, it becomes apparent that goal-setting is of special importance.

3. A further challenge derives from the dynamic complexity of a corporate system (for the distinction between dynamic and static complexity see Sterman, 2000). Frequently, the data or the system structure are not insufficiently known, but their dynamic implications are incorrectly judged (Milling, 1995). Furthermore another conclusion of Forrester states that usually a fundamental conflict exists between the short-term and long-term consequences of a policy change (Forrester, 1971): a policy which produces improvements in the short-run is usually one which degrades the system in the long-run. Likewise, those policies, which produce long-run improvements, may initially depress the behavior of the system. This is especially treacherous as the short-run is more visible and more compelling. Even though it is important that improvement programs show early visible results (Schaffer and Thomson, 1992), it is nevertheless a difficult counterbalancing process between short and long-term goals. If an enterprise is solely focusing on long-term goals, it might not be able to see the wood for the trees, and might end up with a disaffected workforce without any commitment towards change (Fedor et al., 2006; Imai, 1986). On the other hand, early results might jeopardize the overall improvement process in the long-run.

Due to the characteristics and challenges stated above, process improvement programs are the subject of a variety of system dynamics-based studies. (The following literature review does not claim to be a complete listing of all system dynamics based studies in the field of process improvement. In lieu thereof, it provides a short synopsis of previous studies that influenced the present work.) The studies can be classified by respect of the applied method into qualitative and quantitative approaches. As an example of the former kind, Carrol, Sterman, and Marcus (1997) use a case study at 'Du Pont' for their investigation on proactive maintenance programs. They apply a qualitative system thinking approach without formal modeling and simulations, although they use level rate diagrams for model illustration (cf. Sterman, 2000). They discuss a typical 'fixes that fail' archetypical behavior (Senge, 1994), that is, that less proactive maintenance activities increase productivity in the short-run but decrease in the long-run due to increasing equipment downtime. Repenning and Sterman (2001), Keating *et al.* (1999), Repenning and Sterman (1997) as well as Oliva, Rockart, and Sterman (1993) generalize from specific improvement programs and apply system thinking as methodology. Furthermore, the authors use empirical evidence derived from case studies as basis for their research. Beside other valuable findings, they outline that improvement initiatives can facilitate subsequent improvement efforts, if they are evaluated as successful by both managers and workers. However, in the case of low perceived success the same interrelation can also hinder continuous process improvements.

As an example of a quantitative approach, Sterman, Kofman, and Repenning (1997) analyze *ex post* a TQM program at 'Analog Devices'. In their case study, they reveal that due to Analog's TQM program the productivity grew faster than customer demand, and thus Analog experienced excess labor capacity and massive layoffs. The authors provide an extensive model which is highly specific to the Analog case (model documentation is available in Repenning and Sterman, 1994). In spite of the great value of their work to the management literature, the transferability of the model is therefore limited. Maier (2004; 2000) provides two further mainly quantitative modeling approaches, one on TQM and the other on total productive maintenance ([TPM] cf. Nakajima, 1988). In both studies, the author uses empirical data gained from the world class ([WCM] cf. Flynn *et al.*, 1997) and high performance manufacturing project ([HPM] cf. Schroeder and Flynn, 2001) respectively in his analyses. The author provides no model equations and partly omits simulation results. In lieu thereof, the author interprets his empirical findings based on causal loop diagrams. Contrary to that, Thun (2006) analyzes the interplay of different components of TPM and provides all model equations in his article. For this purpose he expands Sterman's (2000) proactive maintenance model by further components that are specific to the TPM approach (i.e., autonomous maintenance and maintenance prevention). His insightful analyses are very specific to the TPM approach and therefore it is only possible to generalize his results to a limited extent. Repenning (2002, 1990) gives a further comprehensive quantitative analysis of the dynamics of process improvement programs. Although the author's focus is on TQM, his findings are transferable on other improvement programs. This applies in particular to his remarks on the 'efficacy spiral' (cf. Lines, 2004; Lindsley *et al.*, 1995) that connects in a feedback loop commitment with allocated effort and perceived results.

The remainder of this paper is organized as follows. In the next paragraph (§2), a generic model of continuous improvement processes is outlined. The purpose of the model is to mimic different process improvement paths of an industrial enterprise, namely *hard* and *soft* improvement patterns respectively. These experiments are useful as empirical studies show that implementation patterns have a significant impact on the long-term success of process improvements (Cua *et al.*, 2006, 2001; Filippini *et al.*, 2001; Vargas and Cardenas, 1999). Yet, the causes of these findings remain largely unclear. For this purpose, the present study attempts to find a structural explanation (i.e., a simulation model). For conceptual reasons, the model exhibits a distinction between process improvement programs and the overall improvement process. The improvement programs represent the path or pattern of process improvement respectively, that is, an enterprise undertakes a hard approach, if—for example—the enterprise shifts its improvement focus to TPM. Likewise, a shift in focus to TQM—for example—implies a softer approach. The overall improvement process ties the varying improvement programs together. That is, it connects the perceived necessity for process improvements (*plan*), workers' and management's effort for process improvement programs (*do*), the perceived outcomes of the improvement programs (*check*), with the gained experiences from process improvement (*act*) in a continuous cycle (for the PDCA-cycle see Imai, 1997, 1986). In the subsequent section (§3), simulation experiments are discussed. In the simulation setting three enterprises are starting from equal initial conditions but take different paths of process improvement, that is, two apply a soft and one a hard improvement pattern respectively. The paper ends (§4) with a discussion of the findings.

A GENERIC MODEL OF CONTINUOUS PROCESS IMPROVEMENT

Building upon both qualitative and quantitative studies, a generic model of continuous process improvement is outlined. Micro structures from previous system dynamics-based studies are applied as building blocks where possible (e.g., from Hines, 2005; Repenning, 2002, 1990; Sterman, 2000; Repenning and Sterman, 1994; and Lyneis, 1988). Figure 1 gives a brief overview of the model structure. The model consists of five sectors:

i) In the human resource section, hiring and laying-off of workers is conducted according to the perceived labor productivity and desired gross production rate. The latter is derived from customer demand, which means that low (high) workers' productivity and comparatively high (low) demand leads to hiring (laying-off) of workers (Hopp and Spearman, 2001).

The training level of the workers depends on on-the-job training provided by management (Armstrong, 2003). Contrary to that, the management cannot control directly gains in improvement experiences of the workers. In lieu thereof, the management provides the workers with some extra time to gain experiences from their conducted process improvements. Those experiences are from outstanding importance for the long-term success of continuous process improvements. This is the case as experiences are the premises for the standardization (i.e., the *act*) of established solutions in the PDCA-cycle (Imai, 1997, 1986). Without gains in experiences, the reached condition cannot be maintained. Workers' willingness to gain experiences from process improvement mainly depends on their program commitment (Armstrong, 2003).

The program commitment deteriorates if the workers perceive a low job security (Meyer and Herscovitch, 2001) and it increases if the improvement initiatives show to be successful (Meyer and Allen, 1991). Furthermore, workers' program commitment depends on the perceived management support (Repenning, 2002; Senge, 1999). Neubert and Cady (2001) show in an empirical investigation that the factors job security, perceived program results, and management support have significant impact on workers' program commitment, and that in turn workers' program commitment is leading towards higher workers' effort for improvement programs. The interrelations between commitment, workers' efforts allocated to process improvement and perceived improvement results represent the aforementioned 'efficacy spiral' (cf. Lines, 2004; Lindsley *et al.*, 1995), which can work as both a virtuous and a vicious cycle (Repenning, 2002; Repenning and Sterman, 2001; Keating *et al.*, 1999; Repenning and Sterman, 1997).

ii) The management provides support to the workers in accordance to the perceived improvement results compared with both, the allocated resources for process improvement and financial stress respectively (Repenning and Sterman, 2001). Furthermore, the sector represents shifts in foci on process improvement programs. The foci are portrayed with exogenous variables. A shift in foci results in a reallocation of resources from one improvement program to another.

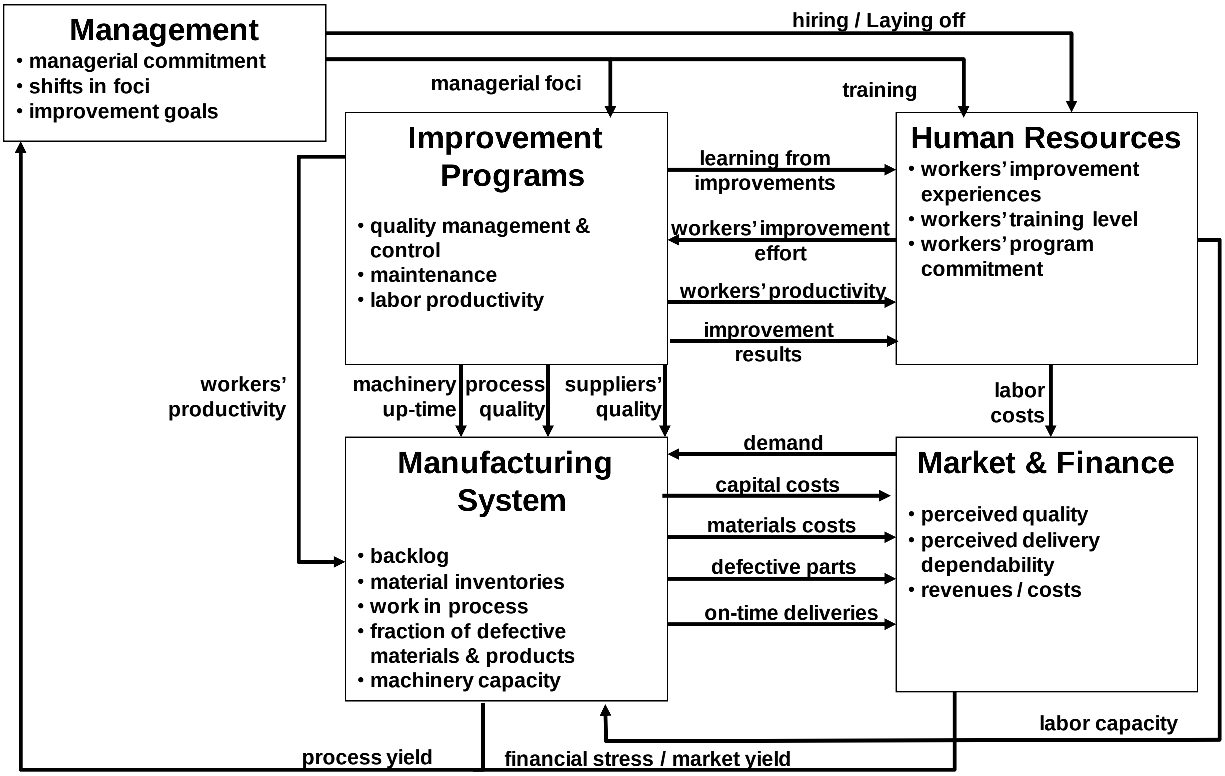

Figure 1: Overview of model structure

iii) The market and finance sector exhibits three figures for plant performance: the 'perceived delivery dependability' for *time*, 'perceived price ratio' for *costs*, and 'perceived quality' for *quality*. The plant loses and gains market shares pursuant to its performance in comparison to its competitors (Hill, 2000). Unit costs are determined by the enterprise's material, labor, and capital costs (Milling, 1974). Decisive for the performance perceived by the customers are the quality and the price of the products as well as the delivery dependability. Product quality and delivery dependability are determined in the manufacturing sector of the model. The sum from unit costs and profit-margin determine the prices of the products. The profit margin is endogenous and hence changes accordingly to a desired market share (Hanson, 1992; Simon, 1989; Cyert and March, 1963).

iv) In the manufacturing system, materials are processed through the production stations and inventories (see also for the following Hopp and Spearman, 2001). In the model, both the supplier and internal production processes can generate defects in raw materials and products respectively. Quality control (cf. Ishikawa, 1985) eliminates some of the defective parts but the remainder is delivered to the customers, which in turn deteriorates the reputation of the plant for quality. In addition, the production capacity depends on both machinery uptime and labor capacity. Likewise, the production lead-time of the manufacturing system depends on the machinery processing time and the available production capacity.

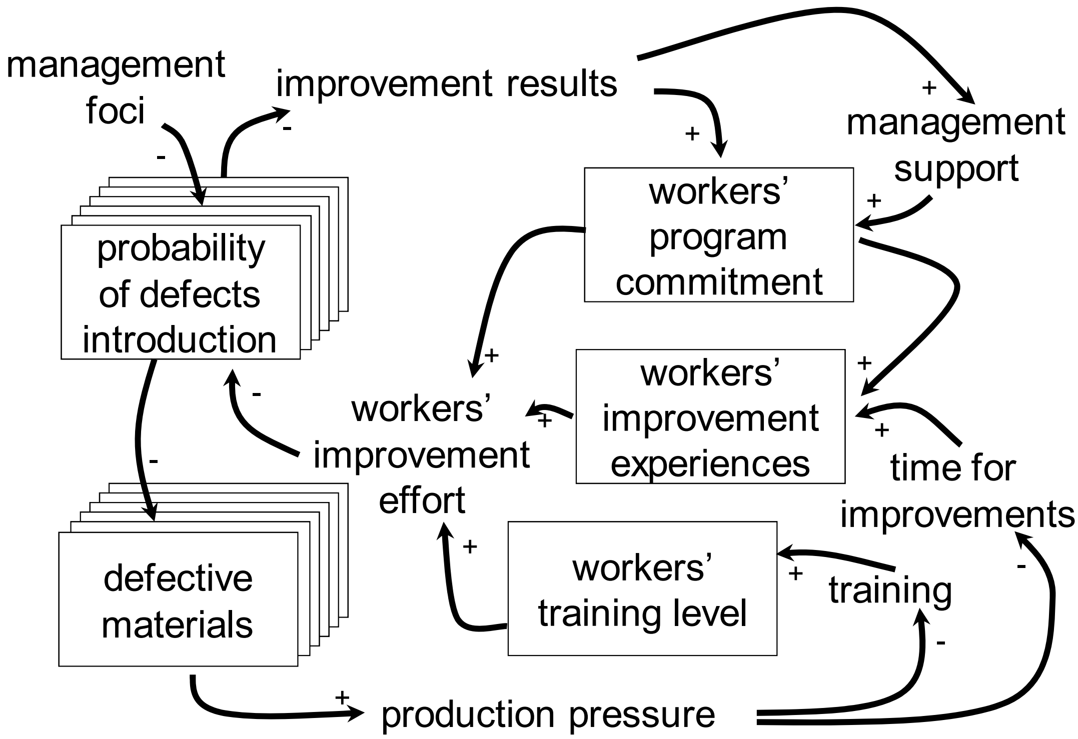

Figure 2: Interactions between management foci, workers' commitment as well as capabilities, and defects levels

v) Every constraint in the production system—suppliers' quality, process quality, quality control, machinery uptime, labor productivity—is represented by a level of defects in the model. In this article, the term 'defect level' is used in its most generic sense according to Schneiderman (1988: 53), like "errors, rework, yield loss, […] unscheduled downtime, […] poor quality", et cetera. Figure 2 illustrates the main interrelations between the sectors 'management', 'human resources', 'improvement programs', and 'manufacturing system'. In the model, each defect level is the target of an improvement program. The varying defect levels (e.g., probability of defects introduction) are portrayed with the stack of tetragons on the left hand side in Figure 2. An adjustment of a 'management foci' variable in Figure 2 mimics a shift in foci from one program to another. The right hand side of Figure 2 illustrates the overall improvement process that connects the different improvement programs together. Both the workers and the management are willing to allocate higher efforts for process improvement, if the improvement programs show expected results. Furthermore, the workers are more willing to gain experiences in process improvement, if the perceived results meet at least their expectations. As mentioned above, gains in experiences are necessary for maintaining the reached condition in process improvement.

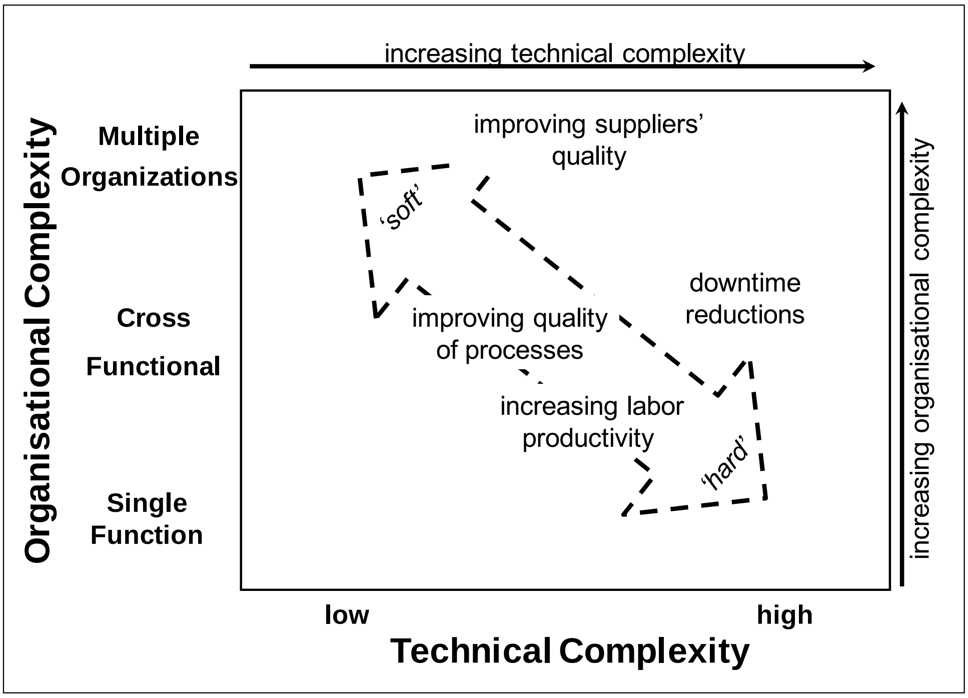

Figure 3: The Half-Life/Complexity Matrix adapted from Schneiderman (1999, 1988)

Schneiderman (1988) finds in an empirical investigation that organizations with ample experiences in process improvement maintain a constant improvement rate, that is, the amount of time necessary for a level of defects to drop by 50% is constant. Therefore, the level of defects exhibits a similar behavior as radioactive decay. Schneiderman shows that the constant half-life times (t_{HL}) increase accordingly to the organizational and technical complexity of an improvement program. He finds that programs, which are placed in the left bottom part of the matrix in Figure 3, exhibit half-life times of approximately one month. Likewise, programs that are located in the right upper part of the matrix have half-life times of approximately twenty-two months. An improvement program in suppliers' quality—for example—involves people from different functions and organizations, and thus possesses high organizational complexity. Contrary to that, the dimension of technical complexity grasps the novelty of the applied technology and therefore an increase in labor productivity features higher technical complexity. The adopted half-lie/complexity matrix with an indication of each improvement initiative incorporated in the present model is illustrated in Figure 3. A shift in focus in the left upper corner of the matrix implies a rather soft approach. Likewise, a shift in the right bottom corner represents a comparatively hard approach on process improvement.

According to the concept of improvement half-life times, an enterprise has to allocate more efforts to complex than to simple programs. For example, comparatively little efforts have to be spend on improvements in labor productivity. However, improvements in labor productivity do not necessarily stimulate demand. Therefore, high improvement rates in labor productivity can lead to excess capacity if demand is not increasing at the same rate. Thus, plants should also engage in improvement efforts that upgrade the enterprise's performance in 'order qualifying' and 'order winning' criteria respectively, like quality and time (Hill, 2000). Lower costs due to higher productivity might not be sufficient to generate higher demand, if price is just an 'order qualifying' criterion.

Schneiderman (1999) also emphasizes the importance of organizational experiences in process improvement. He suggests that plants with low experience in process improvements should start with less complex initiatives and should engage in a process of organizational learning (Stata, 1989). The enterprise therefore can strive for more ambitious improvement programs by means of experiences in process improvements that are gained from less complex programs. This process of organizational learning with the interplay between workers' experiences in process improvement, defects reduction, and process yield is illustrated in Figure 2.

Transforming Schneiderman's original equation to an integral form (1988, 1999), a level of defects (Y_i), its improvement (imp_i) and deterioration rate (det_i) can be calculated according to[i]

$$Y_i = Y_{0_i} + \int (\, det_i - imp_i)\, dt\,; \qquad imp_i = \frac{\ln(2)}{t_{HL\,i}}(Y_i - Y_{\min_i}) * \alpha_i * \beta\,; \qquad det_i = \frac{\ln(2)}{t_{E\,i}} * (Y_{\max_i} - Y_i)\,.$$

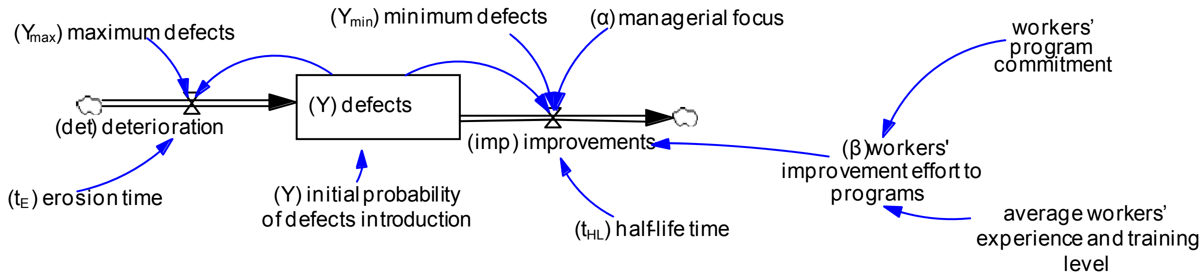

Figure 4: generic representation of defects

One shortcoming in Schneiderman's concept is his explicit assumption that the defects reduction rates (i.e., the improvement rates) are constant over time (cf. Dutton and Thomas, 1984). This implies exogenous underlying learning rates, which are independent from managerial efforts, workers' commitment, and their experiences in process improvement. Contrary to that, Lapré *et al.* (2000) show in a longitudinal empirical analysis that improvement rates are changing over time in accordance to managerial efforts and organizational experiences. In order to incorporate these findings, two further factors—α_i for management focus for defect level i and β for program commitment, workers' skills and training level—supplement Schneiderman's original improvement rate equations in the present model. Therefore, if management is solely focusing on improvements in defects level i (α_i=1) and workers are highly experienced and motivated (β=1) the plant will yield the same improvement rates as outlined in the half-life/complexity-matrix. On the other hand, the defect levels deteriorate to their maximum values if the efforts of the management and the workers are not sufficient.

Figure 4 illustrates the stock and flow structure of a defect level. The outflow represents an improvement, and likewise, the inflow stands for deterioration. Every defect level is represented with its specific initial values, half-life times, erosion times, and management foci towards improvement in the present model. The half-life times are derived from Schneiderman (1988). In its initial state, the model is set into equilibrium[ii]. Without any adjustments to the different foci, the market share goal, or the customers' expectations on quality, time, and costs, the plant maintains its *status quo*.

SOFT AND HARD PATHS OF PROCESS IMPROVEMENT

As outlined before, the simulation experiments mimic different paths of process improvement, namely hard (early focus on the left upper quarter of the matrix) and soft (early focus on the right bottom part) approaches. As illustrated in Figure 5, two enterprises take a path of process improvement with an emphasis on softer programs in the beginning and on harder programs at the end. Contrary to that, one enterprise takes a *vice versa* path, that is, it emphasis hard programs in the beginning and soft programs in the end. However, it is important to notice that all simulation experiments start with equal initial conditions and end up with the same organizational and technical complexity. The simulation runs therefore only differ in the sequence of programs applied (see Table 1).

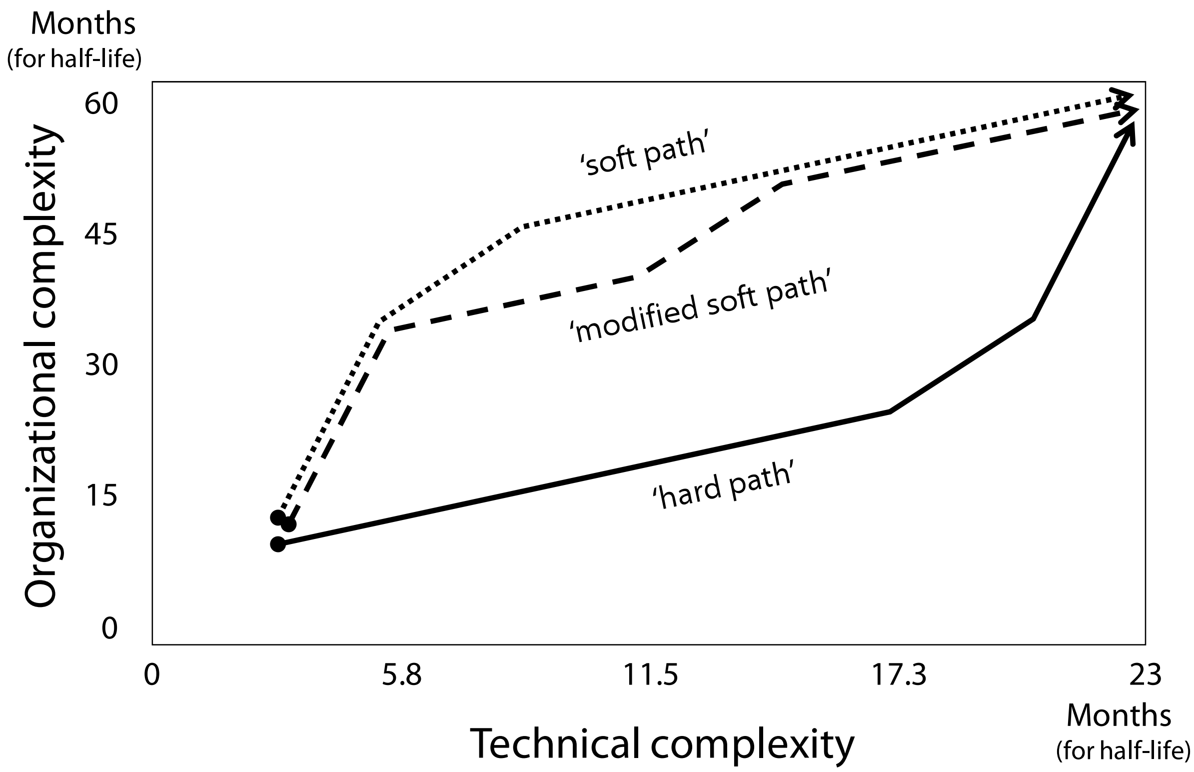

Figure 5: Soft versus hard paths of process improvement

modified soft approach	soft approach	hard approach
improving suppliers' quality	improving suppliers' quality	downtime reductions
improving quality of processes	increasing labor productivity	increasing labor productivity
increasing labor productivity	improving quality of processes	increasing labor productivity
downtime reductions	downtime reductions	improving suppliers' quality

Table 1: Sequence of program introduction

The profitability of the enterprise rises in all simulation runs after a short period with declining profits. In the case of the hard approach, as can be seen in Figure 6, the profitability starts to decrease again after approximately 4 years. Furthermore, the two soft approaches outperform the hard in terms of profitability right from the start.

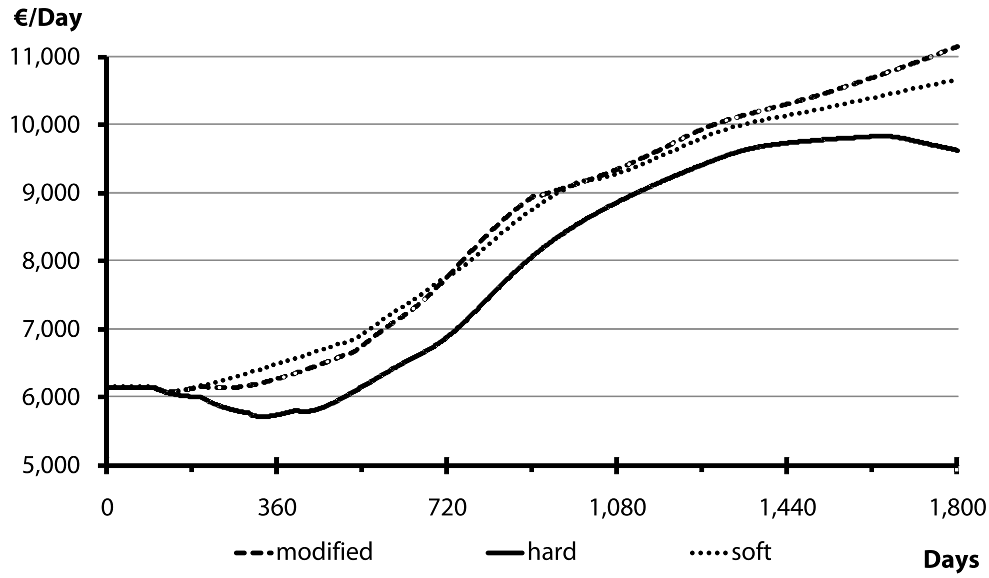

Figure 6: Profitability

Figure 7 displays one reason for the comparatively low performance in profitability in the case of the hard approach. Figure 7 illustrates the percentage of defective parts delivered to the customers, which is an indicator for quality. Quality influences the profitability in two ways in the present model. First, customers' demand behaves accordingly to the perceived quality level by the customers. Hence, the enterprise c.p. loses customers if it delivers products with inadequate quality. Second, inadequate quality implies higher cost due to quality control, rework, and scrap. As can be seen in Figure 7, the enterprise is only able to maintain the reached status in quality in the case of the 'modified soft approach'. In the other cases, the enterprise loses its momentum towards improvement, and the percentage of defective parts delivered to the customers is rising again. However, the quality status erodes faster in the hard than in the soft approach.

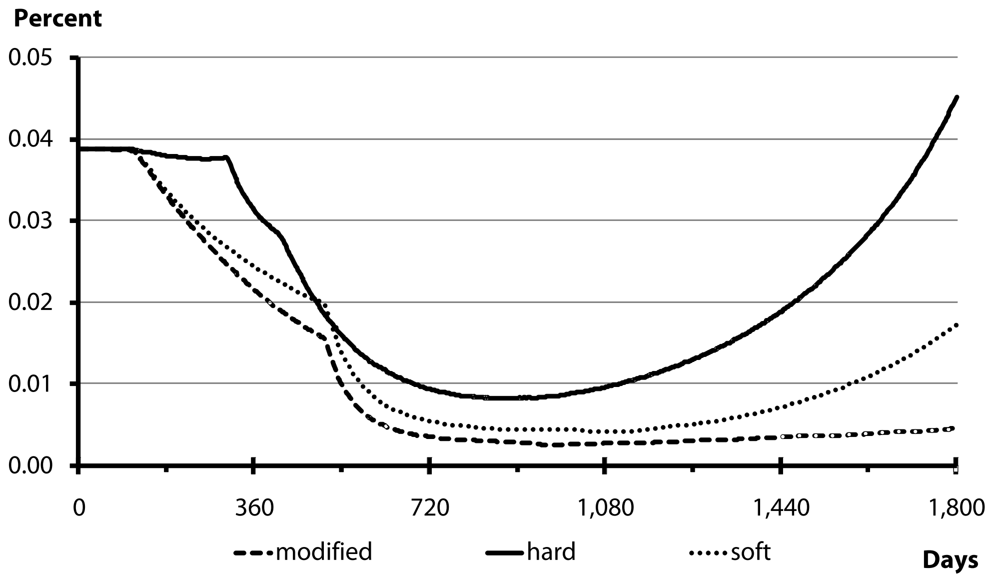

Figure 7: Percentage of defective parts delivered to the customers

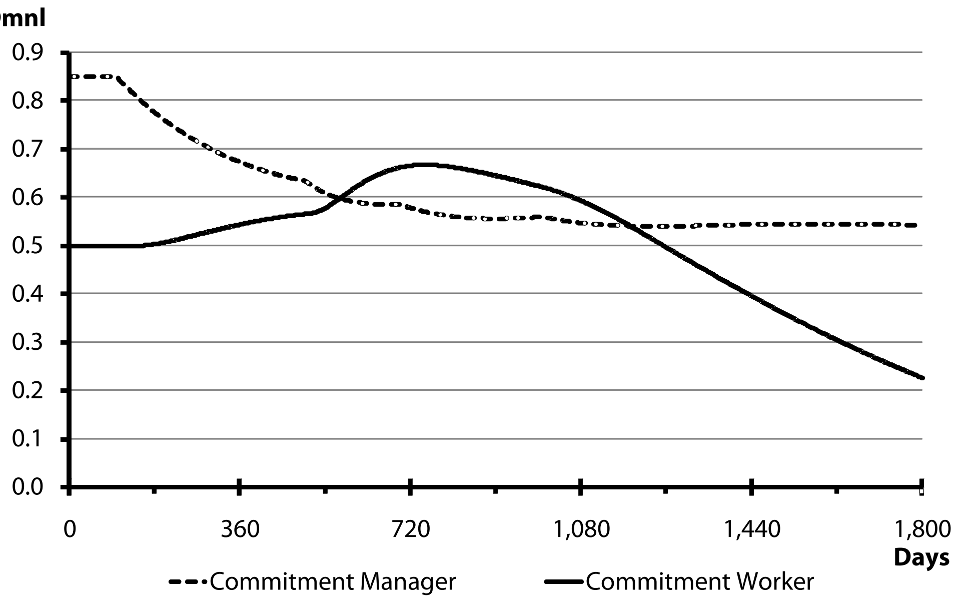

Figure 8: Development of commitment in the pure soft approach

The graphs in Figure 8, Figure 9, and Figure 10 give indications of the momenta towards process improvement in the soft, the hard, and the modified soft approach respectively. The graphs do not differ in their generic gestalt but show different outcomes: the commitment of the management stabilizes on a lower level in the case of the soft and the hard approach. In the case of the modified soft run, the managerial commitment is rising until the end of the simulation. In the soft and hard run, the workers merely lose their faith in the process improvement programs: within 5 years, workers' commitment towards process improvement drops significantly from 50 to 22 and 12 percent respectively. In the modified soft run, the commitment of the workers lies above its initial level at the end of the simulation (56 percent).

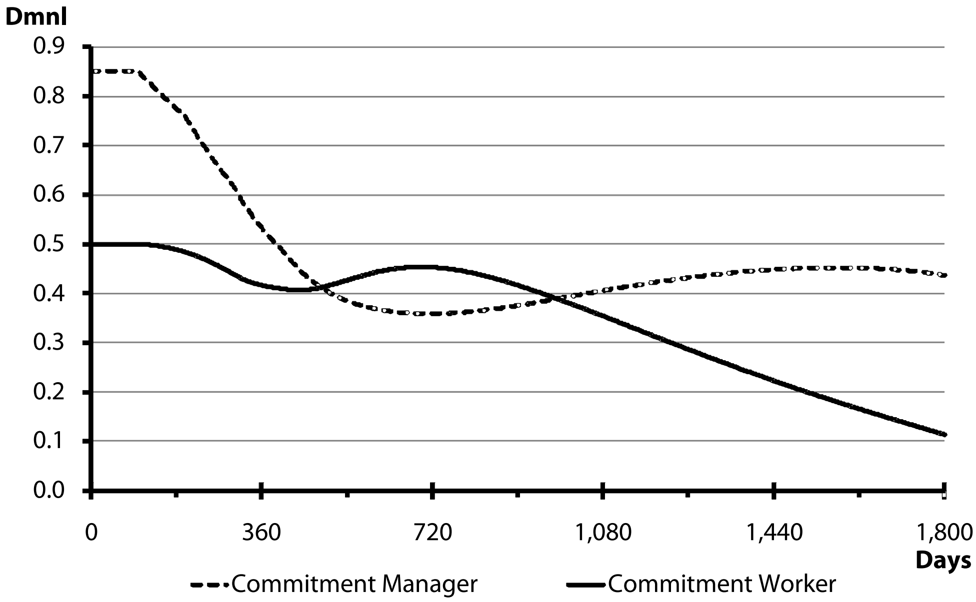

Figure 9: Development of commitment in the hard approach

If one takes a closer look on the early periods of the simulation runs, it can be seen that the workers gain commitment in the first two years of process improvement in the case of the soft approach. Nevertheless, the enterprise fails to stabilize this momentum towards process improvement. One reason for this is that the management itself is losing faith in the process improvement programs rather fast. Thus, the management is not in the condition to provide support to the workforce when the hard programs are next on the improvement path. The managerial commitment declines due to the high improvement expenses in relation to gains in profitability (see Figure 6) and perceived improvement results.

Beside inadequate managerial commitment, Figure 12 and Figure 13 hint on a further aspect of the eroding momentum towards process improvement in both the soft and the hard approach. As indicated in the half-life/complexity matrix in Figure 3, the complexity of the improvement programs grows more strongly, if the enterprise shifts its focus in the organizational (vertical) dimension than in the technical (horizontal) dimension (Schneiderman, 1999, 1988). Therefore, in the case of the hard path, the organization is able to achieve the targeted improvement results c.p. with a lower amount of resources or efforts respectively. This has the consequence that in the first half time of the simulations, the workers have more time available for training and learning as it is the case in the soft approach. In the pure soft approach with an early emphasis on organizational programs, the improvement programs lack to free the workers from workload in the first half time of the simulation. In the case of the soft path, workers have comparatively more time available for training and learning, when the organization is already losing its commitment towards change. Hence, the enterprise fails to maintain its momentum in both cases, in the pure soft and hard approach.

Figure 10: Development of commitment in the modified soft approach

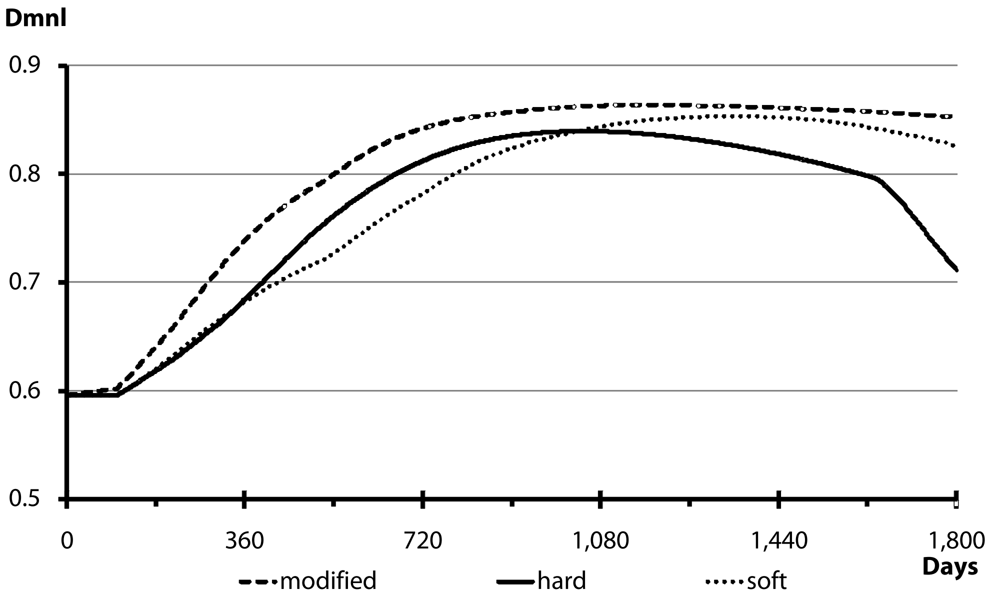

Figure 11: Workers' process improvement capabilities

As aforementioned, goal-setting in terms of process improvement is a demanding balancing process between short and long-term goals: the hard approach fails to stimulate organizational commitment in the first half time, and hence the workers are not willing to allocate efforts in training or learning from process improvements. Although more time is available to the workers in the hard approach, they participate less in training and learning activities due to their insufficient commitment. Contrary to that, the pure soft approach fails to free the workers from workload so that the workers are not able to get sufficiently involved in training and learning activities, even though they exhibit ample commitment towards change (compare Figure 8 and Figure 9). As a result, the organizational capabilities of the workers in terms of process improvement is deteriorating in the hard and pure soft path respectively, with the distinction that the hard approach shows a better performance in the first half time, and that in turn in the soft case the capabilities are eroding at a more steady pace (see Figure 11).

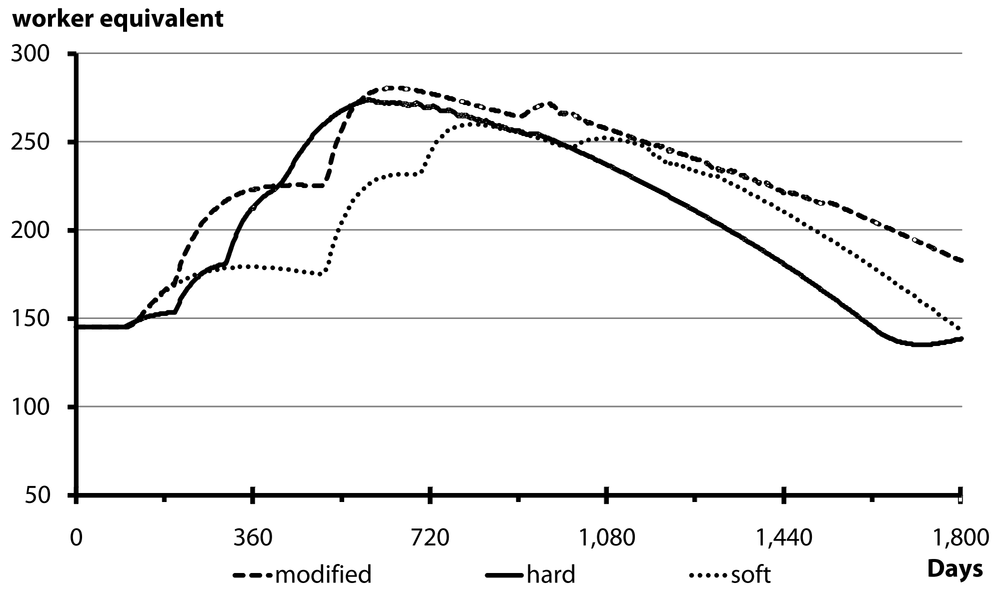

Figure 12: Time available for training

As can be seen in Figure 12 and Figure 13, the 'modified soft path' makes a compromise between the other two approaches. The modified approach mimics a counterbalancing path, with an early focus on organizational programs (i.e., the first steep section in the 'modified soft path' in the half-life/complexity matrix), in which—if necessary—hard programs are applied to free the workers from workload (i.e., the 'kink' in the modified path in *Figure 5* in comparison to the pure 'soft path'). In this case, the enterprise is able to exploit the internal momentum to generate visible improvement results. In addition, the organization is capable to maintain the reached status in process improvement (see Figure 7); the organizational capabilities for process improvement stay on a sufficient level (see Figure 11).

The counterbalanced approach provides a ground for further initiatives in process improvements. Here the concept of process innovations comes into play, which forms a rather dramatic and great-leap-forward approach respectively than the gradual and continuous improvement process (Imai, 1997, 1986), which is under investigation in this paper. On this solid basis with an ongoing momentum towards change, relatively high organizational improvement capabilities, and stabilized states of the internal processes, the investigated enterprise is capable to face nouveau challenges and to undergo even dramatic change processes.

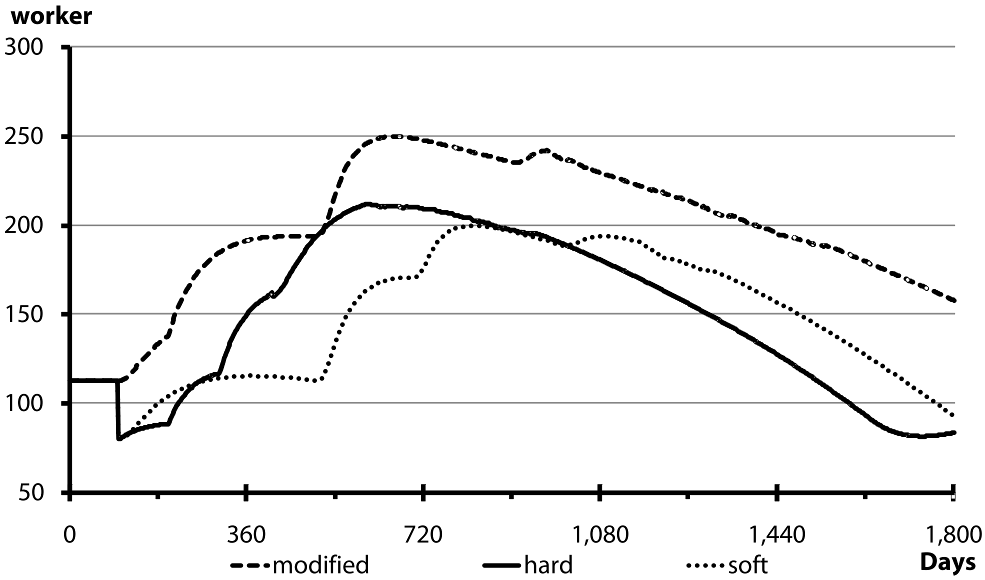

Figure 13: Time available for gaining experiences

PROCESS IMPROVEMENT AS A COMPLEX COUNTERBALANCING ACT

Building on previous work from operations management and system dynamics, the paper outlines a system dynamics model of continuous improvement processes in industrial manufacturing. The model builds the basis for the simulation and discussion of several paths of process improvement, namely hard (i.e., early focus on technical programs) and soft (i.e., early focus on organizational programs) approaches. Empirical studies that indicate a higher favorability of soft paths form the starting point for the conceptual considerations of the present paper (Cua *et al.*, 2006, 2001; Filippini *et al.*, 2001; Vargas and Cardenas, 1999). Unfortunately, these studies offer little to the question of why soft and hard paths exhibit varying outcomes. Yet, the structural causes for these empirical findings remain largely unclear.

The applied formal modeling approach allows for iterative hypotheses testing. From the tested scenarios, four findings can be derived:

1. In order to maintain a reached state in process improvement, an organization has to establish a basis of commitment towards change as well as sufficient levels of training and experiences.
2. Enterprises should strive for paths of process improvement that exhibit a higher degree of organizational than technical complexity. It has been argued that softer approaches contribute better to a development of momentum towards change in an organization.

3. However, soft approaches also bear a danger. While soft improvement programs are more stimulating in terms of commitment, they are also more complex to implement. Hence, softer patterns necessitate c.p. higher efforts on process improvements in the beginning. Under certain circumstances, this can lead to a situation, where the improvement programs show to be beneficial when the organization is already losing its momentum towards change.
4. The management plays a crucial role in an improvement process. First, it is from outstanding importance that the management stays committed with the goals of the improvement programs. Otherwise, the declining managerial commitment can stall improvement efforts of the workers. Second, it is also important that the management communicate realistic improvement goals to their workers.

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i According to Schneiderman (1988, 1999), a level of defects can be calculated at a particular time *t* with

$Y - Y_{\min} = (Y_0 - Y_{\min})\exp(-\phi(t-t_0))$ and $\phi = \dfrac{\ln(2)}{t_{HL}}$,

which can be transformed to $\dfrac{dY}{dt} = -\phi(Y_0 - Y_{\min})\exp(-\phi(t-t_0))$, $\dfrac{Y - Y_{\min}}{Y_0 - Y_{\min}} = \exp(-\phi(t-t_0))$,

and thus the rate of improvement can be calculated as $\dfrac{dY}{dt} = -\dfrac{\ln(2)}{t_{HL}}(Y - Y_{\min})$,

where Y_{min} equals the minimum defect level achievable theoretically, Y_o equals the initial defect level, t equals time, t_o equals initial time, and t_{HL} equals the defect half life. Transformed into integral equations, one receives

$imp_i = \dfrac{\ln(2)}{t_{HL\,i}}(Y_i - Y_{\min_i}) * \alpha_i * \beta$ as improvement rate (supplemented with management focus α_i and workers' effort β), $det_i = \dfrac{\ln(2)}{t_{E\,i}} * (Y_{\max_i} - Y_i)$ as deterioration rate,

and $Y_i = Y_{0_i} + \int (det_i - imp_i)\, dt$ for the level of defects *i*.

ii The different management foci for process improvement initiatives, are therefore set to

$$\alpha_i = \frac{\dfrac{\ln(2)}{t_{E\,i}} * (Y_{\max_i} - Y_i)}{\dfrac{\ln(2)}{t_{HL\,i}} * (Y_i - Y_{\min_i}) * \beta}$$ with $\sum_i \alpha_i = 1$, $0 \le \alpha_i \le 1$, and $0 \le \beta \le 1$