

**SWP 15/98 ENABLERS AND INHIBITORS TO
MANUFACTURING STRATEGY**

**DR ALAN HARRISON
Operations Management
Cranfield School of Management
Cranfield University
Cranfield
Bedfordshire MK43 0AL**

Tel: +44 (0)1234 751122

Fax: +44 (0)1234 751806

Email: a.harrison@Cranfield.ac.uk

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Dr Alan Harrison, Cranfield School of Management
Cranfield, Bedford, MK43 0AL
Tel +44 1234 751122, Fax +44 1234 751806, email a.harrison@cranfield.ac.uk

ABSTRACT

Two radically different views of manufacturing strategy are that it should be developed from the 'top down' by planned integration with corporate strategy, or alternatively, that it should be developed from the 'bottom up' by focusing on improved performance by the elimination of waste. Using comparative, case-based research, this paper casts some light on these opposing views through quantitative and qualitative studies in two very different organisations. Within each organisation, two units of analysis were used to investigate the nature of the tradeoffs, and the role of best practice in manufacturing strategy development. A third set of proposals is made about the development of manufacturing strategy enablers that are available only in given situations.

INTRODUCTION

The literature on manufacturing strategy development can broadly be characterised by two distinctive points of view. The first is the *top down version*: manufacturing strategy must be developed from the top down, that is, by considering first the competitive environment of the firm, and then by aligning strategy decisions in manufacturing with that environment. One of the most closely formulated approaches in this category is that of Hill (1993:36), who advocates five basic steps. First, define corporate objectives; second determine market strategies to meet those objectives; third, assess how different products win orders against competitors; fourth establish process choice; and fifth provide manufacturing infrastructure support. Key issues in this approach are that manufacturing strategy should be internally and externally consistent, and that it should explicitly contribute to competitive advantage (Hayes and Wheelwright, 1984:33).

The second category is the *bottom up version*: which advocates a set of ideals and proposes specific actions for the firm to take. An example of a closely formulated approach here is that of Womack and Roos (1996). Again, five steps are needed. These are specify value; identify value stream; create continuous flow; introduce customer pull; and seek perfection by exposing *muda*. Thus Collins and Schmenner (1993) challenge the top down concept of 'establishing a hierarchical list of competitive priorities and focusing exclusively on the top of the list'. World class competitors 'have mastered quality, delivery, cost and flexibility'. And many authors, such as Hanson and Voss (1993, 1995), assume a clear and positive relationship between best practice – as evidenced by 'world class' metrics - and performance in the market place.

Vigorous views have been expressed about the alternatives. Thus Hill (1993) dismisses bottom up versions as 'panaceas' and Japanese practices as the 'latest in a long line of redundant solutions'. Porter (1996) has added his weight to this side in the debate: 'operational effectiveness is not a strategy'. On the other hand, Womack and Jones (1996:49) urge firms to ignore competitors and to 'compete against perfection by identifying all activities that are *muda* and eliminating them'.

More recent analyses of manufacturing strategy have proposed that there are linkages between the various extremes. Voss (1995) splits the top down approach into two (competing through manufacturing and strategic choices in manufacturing strategy), and refers to bottom up as 'best practice'. 'A company cannot ignore any of these completely, for it would risk losing its competitive strength in manufacturing'. A blend of all approaches is needed because 'together they contain all that is required for an effective strategy'. Pointing to the lack of linkages in strategic models, Swink and Hegarty (1998) propose that manufacturing strategy research should move away from studying the relationship between structures and performance and towards studying the core capabilities themselves. How can core capabilities be better understood, and how can such an understanding help to integrate the divergent views of manufacturing strategy development? The research described in this paper sought answers to such questions by studying the *flow of materials* in different operations contexts. In this paper, flow is defined as the quantity of materials (measured in input terms like litres or tonnes) fully processed through to finished product per unit of time. Flow was used as an integrative concept to describe an operating system in terms of human and technical factors that speed up flow ('enablers') and those that slow down flow ('inhibitors').

RESEARCH DESIGN

In order to explore the dynamics of an operating system and to investigate the social as well as the technical issues at stake, a case-based research design was developed. Case studies in organisational research have been described as a 'research strategy' in themselves (Hartley, 1994). Thus case-based research formed an appropriate 'umbrella' strategy that encompassed quantitative instruments to evaluate the technical issues, and qualitative instruments to evaluate the social issues. The two sets of evidence could then be triangulated (Jick, 1979) in order to seek convergence between the different social and technical issues, to test for competing theories, and to add confidence to the results. Selection of case studies with very different operations environments would provide variety, and would hence test existing theory from very divergent directions.

The two main case studies that were selected were Autoco (automotive assembly) and Filmco (manufacture of polypropylene film). Further contextual details of the two cases have been reported elsewhere (Harrison, 1998a and b). In both of the cases, a major package of organisational and work method changes had been introduced some 3 years prior to the study. The impact of these changes was examined on different units of analysis within the same case study context, thereby ensuring that potential variables such as organisation structure and payment conditions were normalised by the research design. Units of analysis at Autoco were two model lines (Model A and Model B) which ran down the same trim and final assembly track, and at Filmco they

were two process lines (Line 4 and Line 7) in different sections of the same factory. Thus *comparative logic* (Ragin, 1987) was an integral feature of the research design, and the units of analysis were selected within individual cases to display variety in the chosen measures of material flow. As indicated above, material flow is here defined as the quantity of material (measured in input terms such as units, tonnes or litres) which is fully processed through to finished product per unit of time in a given operating system. Investigation of the reasons for changes to flow makes it possible to measure *enablers* (features of an operating system which speed up flow) and *inhibitors* (features of an operating system which slow down flow). Examples of enablers are process and product simplicity, schedule stability and human constructs, which support reductions in inventory and throughput, time. Inhibitors have the opposite effect, and include process and product complexity, schedule instability and human constructs which are opposed to low inventories and short operations lead times.

A number of research instruments were developed to study material flow in an operating system. These instruments were directed at measuring the following hypothesised independent variables:

- *capacity*: the maximum conforming material flow (quantity of material processed per unit of time) for a given product in a given unit of analysis.
- *schedule uncertainty*: the changes in demand for a given product in a given time bucket as it approaches the delivery due date (ie as the time bucket → zero)
- *equipment uptime*: the availability of equipment in a given unit of analysis (total running hours less stop losses)
- *speed*: the actual material flow during running hours compared with capacity
- *quality*: the nett conforming material flow after allowing for defects
- *process simplicity*: the comparative throughput time (TT) and flow distance between one unit of analysis and another
- *product simplicity*: the comparative number of raw materials and finished product offerings between one unit of analysis and another

The above seven variables were not intended to form a comprehensive description of an operating system, but to facilitate a broad-based technical measurement which could be used to identify differences between the units of analysis. These differences would then demand explanation. (Equipment uptime, speed and quality have been grouped together as ‘overall equipment effectiveness’, OEE, Nakajima, 1988).

In addition to the seven quantitative measures, two qualitative measures were developed to describe social constructs of an operating system. Evidence was collected by means of semi-structured interviews, which were transcribed and coded using methods described by Miles and Huberman (1994). Some 25 informants were selected opportunistically in each case environment following a detailed orientation review. The qualitative measures identified:

- constructs of the *impact of the change content* on traditional operating practices. These were collected using the concept of a ‘core operations process’. The orientation review established what this process was in a given firm. A generic version of this process is shown in figure 1 (for a detailed description in Autoco, see

Harrison, 1998a). The core operations process provided a boundary for the study, and facilitated the collection of qualitative data according to the major task categories within that process. While these varied somewhat by operations context, they fundamentally comprised pipeline scheduling (*how many, when*), process specifications (*how*), product specifications (*what*), short term scheduling (*adjust*), and the specific operations tasks (*do*).

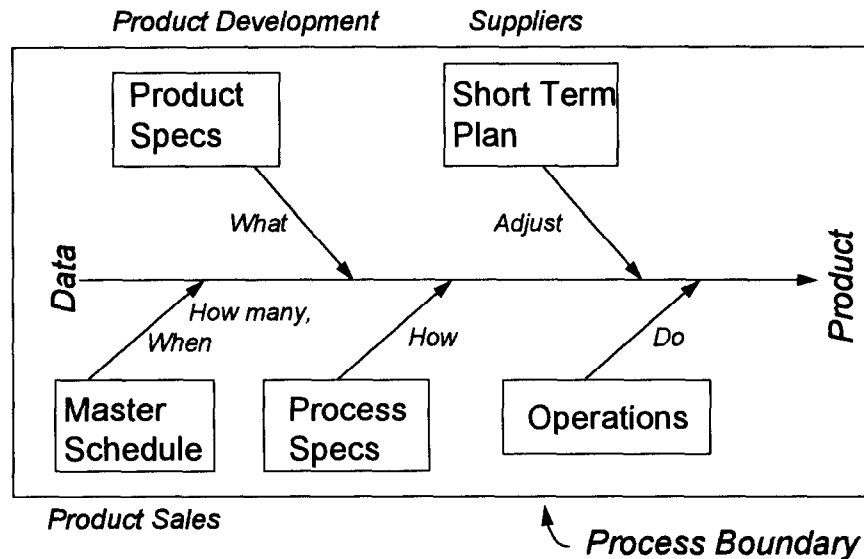


Figure 1: Hypothesised Core Operations Process

- constructs of the *human control categories* hypothesised to differentiate between types of operating system, detailed in the Shimada (1993) humanware model which describes the integration of machinery and human relations. The Shimada categories are self management, self inspection, continuous improvement, visibility of information, building quality into the process, and giving wisdom to the machine (through automation, error proofing and the like).

By investigating both technical and social variables at the same time in the same case study environments, convergence between technical and social issues was sought.

Rigour in Case Study Design

A major concern with case study research is rigour in its design. Yin (1994:33) lists four tests commonly used to establish the quality of any empirical research, which are concerned with replicability. These were addressed in the research design as follows:

- *construct validity*: operational measures were first established and tested in a pilot study, which has been reported earlier (Harrison, 1998c)
- *internal validity*: by comparing units of analysis within the same case study environment, the aim was to neutralise the impact of extraneous contextual variables, such as organisational structure, and thereby to focus on differences between those units of analysis using the same research instruments

- *external validity*: use of the same research instruments in each case facilitated cross case comparisons to be made on common criteria
- *reliability*: was again facilitated by first proving the research methods in a pilot study. Use of many instruments (7 quantitative and 2 qualitative) provided broad-based comparisons against which errors would be exposed. A second researcher independently carried out interpretation of qualitative evidence.

A further concern with case study research is that of lack of generalisability. There was no statistical significance to the sampling logic behind the selection of cases or units of analysis - or for the selection of informants within the units of analysis. The underlying logic behind selection was that of creating sufficient *variety* for the constructs behind the manufacturing strategies at each firm to be tested from very different viewpoints. The resulting generalisations are therefore analytical rather than statistical. Case study findings should be *generalised to theory* 'analogous to the way a scientist generalises from experimental results to theory' (Yin, 1994:37).

RESULTS

Table 1 collects together the main conclusions in much summarised format from the quantitative studies at Autoco (Models A and B) and Filmco (Lines 4 and 7). Collection of the data by means of the same research instruments facilitated the juxtaposition of evidence in this way:

<i>Enabler</i>	<i>Model A</i>	<i>Model B</i>	<i>Line 4</i>	<i>Line 7</i>
<i>Capacity</i> - <i>load</i> - <i>setups</i>	lower: less intensive work cycle short, simple, after each batch	higher: more intensive work cycle short, simple, each car	continuous, high loading in each process lengthy, can be complex	continuous in making, intermittent in slitting & packing short, simple
<i>Schedule Uncertainty</i>	high: schedules determined 4 months prior to build day	low: continuously changed up to & including build day	reducing: more, smaller campaigns	relatively static, stable. Changes have low impact on line operation
<i>OEE</i> : - <i>uptime</i> - <i>speed</i> - <i>quality</i>	not applicable not applicable better: fewer defects/100 vehicles	not applicable not applicable worst in Autoco group	increasing: reliability ↑ increasing: consistent imp't falling: more setups	falling: equipment reliability ↓ targets not achieved improving
<i>Process Simplicity</i> - <i>TT reduction</i> - <i>flow distance</i>	not applicable shorter: fewer operations, less lineside inventory	not applicable longer: more ops, more lineside inventory	linespeed ↑ no change	linespeed ↓ no change
<i>Product Simplicity</i> - <i>raw materials</i> - <i>finished products</i>	lower: 2100 components lower: 180 derivatives	higher: 2800 components higher: 1000 derivatives	Higher: 22 components) higher: 4 lines, 7 products	Lower: 4 components lower: 1 line, 5 products

Table 1: Comparing Enablers for Units of Analysis at Autoco and Filmco: Summary of Quantitative Evidence

A. Capacity: the core operations process can be envisaged as a pipeline into which finite quantities of raw materials and data are loaded. Limits to the permitted quantities that can be processed within a given timescale are measured in output units (vehicles per hour at Autoco and tonnes per hour at Filmco). The assembly line at Autoco had the effect of integrating many assembly processes in the same way as film making at Filmco. Such integration has the effect of creating *fragility* in the core process: a problem with a given activity affects the whole process. Loading on the assembly line at Autoco was heavier on model B because of its greater complexity and thus more intensive work cycle. Available capacity on the system was wasted when model A was run. On the other hand, load was continuous and high on the making processes on both lines at Filmco. But it was only intermittent on line 7 slitting and packing, which were only weakly integrated with making because of the effects of the 'lag store' (between making and slitting) and the conveyor belts after slitting. Available capacity on these later processes was wasted by such problems as extension of effort by the operators. Overall, the *demonstrated capacity* of line 7 had been falling over the 2 years prior to the study, due to an accumulation of human, facility and management problems, as shown in figure 2:

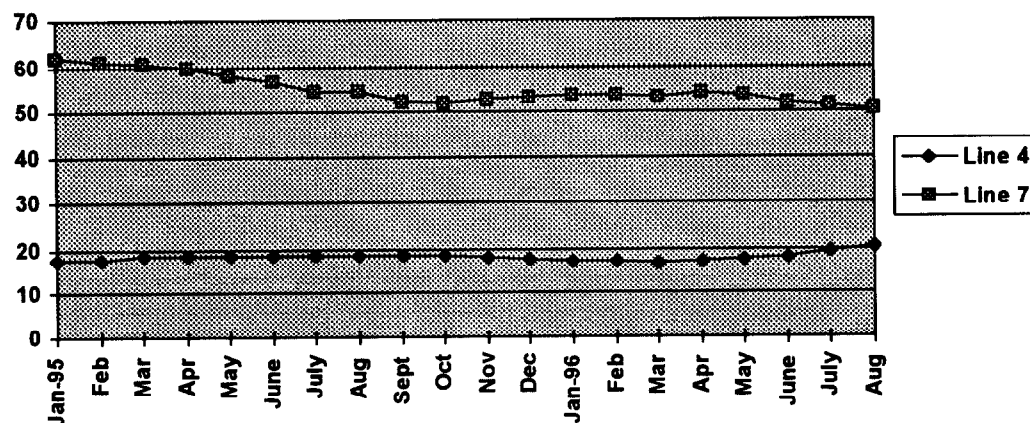


Figure 2: Trend of Demonstrated Capacities for Lines 4 and 7 in Tonnes/Month

The other dimension of capacity, which was measured, was setups, which also reduce capacity. Thus changeovers on the BIW framing line at Autoco and rolls lost at Filmco during changeovers between different formulations consumed available running hours. Setups were of relatively short duration at Autoco and on line 7, but were a significant problem for line 4 where they not only reduced capacity but also reduced yield (quality). Demonstrated capacity can be viewed as the nett effect of 'flow rate variables' (Mather, 1988:18), which control a resource's real capability to produce product. The pipeline is constricted by the combined effects of problems like breakdowns, shortages and rework.

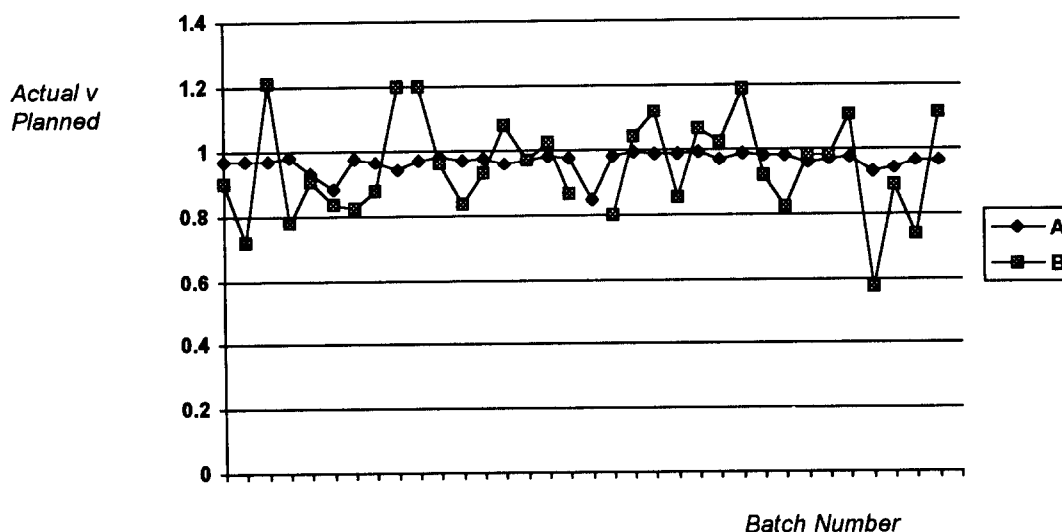


Figure 3: Planned v Actual Volume Achievement for Models A and B (Autoco)

Turbulence was much less apparent at Filmco making processes because of the effect of a 10-day ‘frozen’ period in master scheduling. The core operations process was *cushioned* from the effects of instability in the market place. Allowing schedule instability like that on model B at Filmco would not be practicable because there would be chaos on the making lines, and packaging materials (which are called up within the 10-day firm period using super BOM’s) would be unavailable in spite of huge stocks. Thus the process at Filmco enforces discipline in manufacturing planning and control systems design and operation.

C. Overall Equipment Effectiveness (OEE): a clear picture of the three components of OEE (uptime, speed losses and quality losses) was only obtained at Filmco, where they were already well documented. Thus at Autoco, OEE data was of doubtful value: system efficiency (actual v planned build) ran at around 89% on average, but contributions to the remaining 11% were many and variable. Quality losses were also doubtful in that errors in the assembly process were caught at a number of stages (within the team, at other track stations, and at off-track rectification), which did not incur production losses. Thus it was decided to use the internal QA audit scores for the two models as a substitute for quality losses: this was a quality measure that was clearly related to the specific units of analysis under study. The QA scores (16.5 for model A and 23.9 for model B) showed further problems for model B, and highlighted issues of relative product complexity and difficulty of build.

However, such difficulties of data collection should not rule out OEE as a measure. At Filmco, it had become the major measure of factory performance, and was thus well documented. It helped to contrast the two lines in terms of operating policies, which was important in providing evidence in terms of how they were being managed. Thus speed losses were shown to be particularly strongly related to OEE in the case of line 7, which supported qualitative evidence given below. Further, OEE is closely related to demonstrated capacity, and can be used to identify the ‘flow rate variables’ referred to in A. above.

D. Process Simplicity: geographical forces were at work at Filmco, where the north factory operation was more compact and integrated than south factory. Layout studies showed that line 4 involves much smaller areas for the team leader to supervise, and for team leaders and process technicians to coordinate with each other. Slitting and packing operations were an internal part of the process, kept under continuous pressure by the consistent performance of the making line. Thus, line 4 helped to show that improvements in output variables are enabled by geographical proximity. Line 7 showed that the relative disconnection of slitting and packing, and the physical barrier of a fire wall in front of packing, were inhibitors.

But process simplification can apply to more than process length reduction. Thus, line 4 at Filmco showed the power of simplifying and standardising *process specifications*. Line 4 management had given top priority to removing sources of operator discretion as much as possible, for example by removing the wheels from the chain profile adjusters so that they could not be turned.

E. Product Simplicity: this was a clear enabler at Autoco, where reduced raw material and finished product part numbers helped to facilitate lean logistics systems for model A. Reductions to numbers of finished products on line 4 at Filmco had been one of the enablers of improved performance stated by the management team (the others being engineering improvements to the line and the establishment and acceptance of standard conditions). However, line 4 still had a far greater product complexity than line 7, and this tended to drag down its performance because of more product changeovers. This was overcome by line 4's superior performance in the other two areas.

Enablers and Inhibitors to Flow: Qualitative Evidence

Continuing the comparison of hypothesised enablers and inhibitors to flow, we next turn to the qualitative evidence. This is summarised in table 2, where evidence has been identified as enablers or inhibitors against the six categories of human control identified in the Shimada model. Comments have been labelled A (Autoco), or F (Filmco) to indicate their source.

<i>Shimada Category</i>	<i>Enablers</i>	<i>Inhibitors</i>
<i>Self Management</i>	multi-skilling means that you don't have to wait for fitters: you get on with it (F) flexible systems that allow discretion (Model B) cell members take over tasks like truck driving & scheduling (F)	'top jobs' that are more highly skilled and which incumbents don't want to relinquish (F) imposed, inflexible systems that cannot be changed (A) indirect tasks not delegated in assembly (A)
<i>Self Inspection</i>	we've all been trained in QC (F) operator signoff (A, F) well documented process specs (A,F)	functional barriers between logistics and production that mean you don't flag up impending problems (A)
<i>Continuous Improvement</i> <i>Continuous Improvement - ctd</i>	ownership by all team members (F) allow time for improvement projects (F) major changes give teams plenty to get their teeth into (line 4) making the job easier (F)	imposed, inflexible systems that cannot be changed (A) ponderous PCR systems (A) end of life model (model B) expensive projects (F) waning interest by mgm't (F) team members who won't buy in (F)
<i>Visibility of Information</i>	stable information (A, F) plenty of cameras, monitors; process control system (F)	full system was never explained (Model A) hidden processes (line 7 packing)

<i>Build Quality into the Process</i>	operator flexibility creates greater awareness (F) mgm't actions: eg capital spend that proves quality is top priority (F)	poor quality in making cannot be recovered in slitting (F) mgm't actions that promote quantity over quality (A)
<i>Give Wisdom to the Machine</i>	rigid system, clear rules (A) robust process: tell tales, operator checks, machine checks (A) standard conditions (F)	last minute changes, poor documentation (A) fragile processes where many variables must be controlled (F) pressure/overload (F)

Table 2: Comparing Enablers and Inhibitors - Summary of Qualitative Evidence

A. Self Management: empowerment of the operator to manage the process was enabled by multi-skilling so that cell members could take over indirect tasks such as maintenance, truck driving and cell scheduling. I heard no dissenting views expressed across the 2 cases: people mostly found such changes motivating. The model B system at Autoco allowed more self management because it was more flexible and totally under Autoco's control: the production system on model A was seen as imposed from outside and as unduly inflexible. This is an example of the contradiction between enablers to which I return later: when it came to giving wisdom to the machine, the roles were reversed, and it was the rigidity of the model A system that was perceived to be better than the license of the model B system. But multi-skilling had its limitations: team leaders at Filmco felt that excessive flexibility was counter-productive and created 'jacks of all trades, masters of none'.

B. Self Inspection: Filmco had gone a long way to remove barriers between direct and indirect tasks, and cross-training had been an important enabler to this end. Autoco still had much to do in this area: for example, production teams and logistics teams were largely independent of each other.

C. Continuous Improvement: this category is enabled by the challenges of change and ownership. Thus focusing the factory into two business units gave Filmco teams the incentive to improve their own processes: operation restructure had left the teams straddling all lines with an unclear sense of ownership. TPM projects waxed when teams worked on their own problem issues, had the time allocated to do so, and involved all team members. They waned when team members felt no sense of appreciation for their work, and when lengthy delays were created by delays in approving major project spend. While some people I had spoken to did not want to get involved in improvement projects, those who did felt that making life easier for themselves was an incentive in itself. This contradicted the views of Turnbull (1988:18) and others that work is intensified under JIT, and that added stress is 'endemic in the system'.

D. Visibility of Information: stability of process control and product information was quoted at both Autoco and Filmco as being a desirable state. It was essential that such documentation was easy to read and available on the shop floor for production personnel in the presence of a high level of labour flexibility. As might be expected, the relatively technical Filmco processes were not only well documented but also made very visible through the process control system, and through liberal use of aids such as cameras and mirrors. Poor visibility of the new systems for model B at Autoco had

been a longstanding problem, which created lack of coordination between activities. Lack of visibility of the line 7 packing operation at Filmco led to weak supervision and poor control. This inhibitor was sufficiently strong to overcome the self management enabler.

E. Build Quality into the Process: cross training helped to build quality into multi-activity processes as a result of wider process understanding. This was apparent in both of the lines at Filmco, where linestop authority had long been a factor for safety reasons, although it was a more recent innovation at Autoco. Such management support that quality comes first was fundamental to this enabler. Equally, the traditional importance of numbers was an inhibitor at Autoco.

F. Give Wisdom to the Machine: the rigid and uncompromising rules were features of the model A system at Autoco that enabled wisdom to be nurtured ('do it the same way the same time every time'). This was further enabled by product design that meant a component could only be fitted one way. Line 4 at Filmco had approached this category by introducing standard conditions. Wherever possible, fixed line conditions were introduced and the discretion of the operator removed. In a potentially multi-variate process, this helps to narrow the field considerably in the event of trouble. There is an apparent inconsistency here with self management, which requires later analysis. Filmco also provided examples of inhibitors to this category in the packing area of line 4, where work overloads caused activities like check weighing the reels to be missed.

CONCLUSIONS

Based on this hypothesised core process, evidence can be collected to indicate how it may be enabled and inhibited in terms of the basic task of converting data into materials. A summary of evidence collected from the case studies is shown in table 3:

Activity	Enablers	Inhibitors
Medium Term Production Planning	long campaign lengths, large batch sizes contained variety - fewer ways to get the forecast wrong, fewer changeovers flexibility to reconfigure supply to demand as late as possible	long 'firm' periods create distance from market demand (Model A) uncertainty of true operations capability (line 7)
Product Specifications	fewer product specs, contained variety fewer components variety yes, complexity no	incompatibility between product spec systems (Model A v Model B) ponderous PCR systems that slow down change (Autoco)
Process Specifications	standard conditions (line 4) error proof processes: only one way to make/build (Model A) simple processes, fewer standard containers, no preparation needed	product complexity \Rightarrow process complexity \Rightarrow low productivity, conformance quality lack of process knowledge (line 7) inconsistent process development (packing at Filmco)
Short Term Production Planning	no changes to medium term plan (Model A) process reliability (line 4) pressure from preceding operations to perform (line 4 slitting & packing)	incomplete campaigns/stragglers obstinacy over permitted changes means responsiveness \downarrow (model A) process unreliability (line 7) lack of pressure (line 7 slitting & packing)

Operations	process integration, short distances between processes (line 4) schedule and process stability	over complex equipment ⇒ more breakdowns, MTTR↑ (line 7) pushing facilities beyond their capabilities (line 7)
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Table 3: Enablers and Inhibitors in Core Operations Processes

This list of enablers and inhibitors contains few surprises from a point of view of OM theory. But what is more problematic is to sort out what is the best set of tactical decisions in a given operations situation. There is an apparent difference between how the enablers and inhibitors might be applied. Three categories can be advanced:

- *tradeoffs*: where an enabler is good for creating operations advantage in one area only to cause inhibition in another. For example, long ‘firm’ schedule periods are good for supply chain and operations stability, but bad for market responsiveness (Model A at Autoco).
- *best practice*: where an enabler is clearly the best course of action in any operations situation, and the equivalent inhibitor is clearly less competitive. Thus process reliability is always better (more competitive) than process unreliability (line 4 example).
- *specific*: where an enabler creates an operations advantage in a given (specific) operations situation. Thus batch build of 30 derivatives at a time for model A at Autoco was consequent on the ‘long firm schedule’ enabler, and could not have been applied without that enabler *and* reduction in the number of derivatives. Batch build combined with pallet factors of 30 was a major enabler of synchronised flow in the supply chain. Such enablers do not have equivalent inhibitors (unless the advantages are to be discarded!)

The first category aligns with Schmenner and Swink’s (1998) *law of tradeoffs* which recognises that a manufacturing plant cannot simultaneously provide the highest levels among all competitors of product quality, flexibility and delivery at the lowest manufactured cost. The second category (‘best practice’) aligns with their *law of cumulative capabilities*, which recognises that improvements in certain manufacturing capabilities (eg quality) are basic and enable improvements to be made more easily in other manufacturing capabilities (eg flexibility). However, Schmenner and Swink have nothing to encompass specific enablers, and their theory of operations management is incomplete in a number of other respects. Firstly, their claim that ‘the law of tradeoffs is reflected in comparisons across plants at a given point in time’ is not borne out by the evidence from the research described in this paper. Tradeoffs are no less dynamic than ‘cumulative capabilities’, which they describe as ‘reflected in improvement within individual plants over time’. Secondly, Schmenner and Swink do not recognise the possibility that their laws are *not complementary*, and have boundary conditions in practice. The ‘laws’ also have negative conjugates, which are better described by my concept of *inhibitors*.

Some inhibitors do not have enabler equivalents. Thus ‘pushing facilities beyond their capabilities’ was due to a series of actions taken by line 7 management team aimed at increasing linespeed. Instead of improving capacity and productivity, this action was in fact creating a vicious cycle of inhibition such as more downtime and reduced pressure

on slitting and packing, the reverse of what was intended. Thus we can distinguish three types of inhibitor corresponding to the enablers listed above:

- *tradeoffs*: the negative conjugate of the enabler category above. These are inhibitors that are caused by enablers in a different operations area (such as market remoteness of Model A caused by lengthy stable schedule periods).
- *bad practice*: where an inhibitor creates anti-competitive properties in the operations system. Unfortunately, this may not be apparent to the management of the day, as in the line 7 linespeed example just given.
- *specific*: where an inhibitor has been allowed to develop in a specific situation. An example is the 'anarchic' packing process at Filmco, which does not fit with the continuous film making and large batch slitting process types that precede it.

Maximising enablers in a given core operations process is therefore something of a minefield, which demands optimising tradeoffs and taking advantage of best practice and specific enabler possibilities where possible. It also demands avoiding or rooting out worst practice and specific inhibitors. However logical this may appear, such action had not been systematically applied in the cases studied, and as a result had left a trail of unresolved problems and inconsistencies in the operationalisation of manufacturing strategy.

The Hypothesised Humanware Model

The hypothesised core operations process analysed in the previous section also acted as the boundary for the qualitative studies. Here, the framework was the hypothesised Japanese 'humanware' model, which was used to determine the coding categories for the qualitative research analysed in Table 2 above. Human control enabler and inhibitor categories can be advanced, which are analogous to the quantitative categories based on the core operations process listed in table 3. The proposed human control enabler categories are:

- *tradeoffs*: which enable human control in one area only to cause inhibition in another. Thus a rigid material planning system was good for 'giving wisdom to the machine' in that a consistent, unchanging production programme was broadcast to everyone who worked in the system. But the very rigidity that was good for 'wisdom' was bad for self management, where the inflexibility cramped initiative. This conclusion mirrors that of Klein (1991), who comments on the clash between autonomy and discipline.
- *best practice*: where a human control enabler is clearly best practice in any situation. Thus teambuilding and flexibility are common enablers across the three cases that facilitated greater process understanding and sensitivity: 'we look out for each other more'.
- *specific*: human control enablers that may be applied opportunistically in a given situation. Thus re-grouping work teams around product lines created an enhanced feeling of familiarity and ownership at Filmco.

Similar arguments can be advanced about human control inhibitors:

- *tradeoffs*: the negative conjugate of tradeoff enablers. Tradeoff inhibitors are the downside of enablers that may appear to possess only positive benefits. While the Model A production system used at Filmco was orderly and disciplined, it provided little opportunity for operators to use their initiative.
- *bad practice*: are inhibitors, which lead to anti-competitive behaviour in any operations system. An example was functional barriers that inhibit process integration, such as observed between logistics operations and the assembly operatives at Autoco.
- *specific*: are inhibitors, which lead to anti-competitive behaviour in specific situations. For example, comparative lack of process change led to inhibition in the line 7 packing operation at Filmco.

Thus it is possible to argue that maximising human control enablers is also a potential minefield. It is for example doubtful if all of the ramifications of the package of organisational and work method changes at Autoco were thought through in terms of what was needed from operatives who were to assemble model A when it was added to the traditional model B production system. Or whether the impact of one model that demanded *high levels of self management* (Model B) on one that demanded *unquestioning discipline* (Model A) was also considered when both had to be produced on the same system.

Implications to Practitioners

The evidence presented in this paper catalogues issues of implementing manufacturing strategy 'at the coal face' in two very different firms. Within both firms, substantial differences in performance between *two comparable units of analysis* arose following implementation of *the same package of changes*. These differences raise important implementation issues from a practitioner perspective. First, re-focusing the factory into smaller, more autonomous units is no guarantee that manufacturing performance will improve. Line 7 at Autoco followed a results-oriented implementation programme, where the emphasis was on increasing linespeed. Performance in terms of output tonnage/day worsened by more than 20% from the time that the package of changes was introduced. Line 4 followed a process improvement route, and developed increasing output capability. I formed a similar conclusion from earlier research into implementation of cellular manufacturing (Harrison, 1998c). Thus, implementation of 'new wave' manufacturing methods and innovative HR policies may lead to performance reduction. Second, the development of manufacturing capabilities can be viewed in terms of enablers and inhibitors referred to above. This problematises the relationship between 'top down' and 'bottom up' versions of strategy development, and demands that boundary conditions between tradeoffs and best practice are understood in both technical and human terms.

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