Exploring the seminal origins of key operations management developments

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Summary Abstract
The purpose of this paper is to explore the underlying systems approach associated with key developments in operations management, namely operations strategy, TQM, lean supply and TOC. These developments are shown to have embraced a paradigm shift in both thinking and practice which reflect a common systems perspective. However, this perspective has been interpreted in different ways to address the needs of different operations environments at different times. Through analyzing the originating literature the underlying conflicts and key developments have been explored as a means of clarifying the seminal contributions. This is then used to better understand the assumptions associated with these distinct developments providing a basis for extending such applications into other environments.

Keywords: Operations strategy, Operations theory, Operations laws

Introduction
A recent IJOPM paper (Boer et al., 2015) raised the question over the relationship between high-level operations management theories, such as the theory of Swift and Even Flow (SEF) and Performance Frontiers (PF) (Schmenner and Swink, 1998) and developments in operations management, such as Lean operations and Total Quality Management (TQM). These more practitioner led developments were considered to embrace multiple lower level theories rather than embracing theory at a higher level.

These now ubiquitous developments have had wide implications on practice that can clearly be associated with lower level theory, but this paper explores whether their seminal origins can be allied more closely with higher-level operations management theory as well as more academically derived developments, such as manufacturing strategy. This paper specifically considers the seminal originators of manufacturing strategy (Skinner, 1969), Total Quality Management (TQM) (Shewhart, 1931), Lean (Ohno, 1988), and the Theory of Constraints (TOC) (Goldratt, 1990).

The paper is structured as follows. The research method outlines the focus on seminal developments and the associated resolution of design conflicts and contradictions, which is used to provide a common means of interpreting the underlying assumptions. The originating literature associated with each of these approaches is explored in identifying the key innovation. Common themes are then discussed referring to operations management laws and theory in distinguishing the underlying assumptions. The paper concludes with a table attempting to summarise these distinguishing aspects.

Methodology

Innovation is closely associated with breaking established conflicts or trade-off relationships, whether considering physical products (Altschuller, 1999) or complex organisations (Goldratt, 1990; Stratton and Mann, 2000). Such breakthroughs are closely associated with not only a paradigm shift in thinking but also practical tools to establish a change in practice. The primary purpose for this study is to explore the origin of these developments in an attempt to identify the seminal innovation that addressed the underlying conflict. It is therefore necessary to identify the conflict together with the underlying assumptions challenged through the innovation. The primary source of evidence in each case is the originator and his/her close associates which limits the literature to be explored in the first instance. This analysis is used to develop hypotheses, which are to be more rigorously tested against wider evidence including established theory.

Seminal origins

The operations management developments are explored in turn identifying the underlying conflict as well as the key innovations. The origins of manufacturing strategy is considered first before looking more deeply into the conflict resolution associated with TQM, lean and TOC in that order.

Manufacturing strategy - Skinner

Skinner is widely acknowledged as the originator of the concept of manufacturing strategy which provides a good introduction to the underlying conflict at a more generalised level.

Using case examples, Skinner highlighted the repeated mistake of considering low cost and high efficiencies as the manufacturing objective.

> *"The connection between manufacturing and corporate success is rarely seen as more than the achievement of high efficiencies and low costs."* (Skinner, 1969: 136)

He claimed that this technical image, associated with production matters, results in top executives delegating excessive amounts of manufacturing policy to subordinates and failing to align these choices with the market needs. Skinner advocated a contingent approach to manufacturing management stressing the need to recognise the strategic impact of the trade-off choices currently being made at the operational level.

He therefore argued that delivery systems need to be designed so the sub-functional trade-off choices are strategically aligned.

'Its [manufacturing] management concepts are outdated, focusing on cost and efficiency instead of strategy, and on making piecemeal changes instead of changes that span and link the entire system.' (Skinner, 1971: 62)

'The prevalence of "cost" and "efficiency" as the conventional yardsticks… for planning, controlling and evaluating… played a large part in the increasing inability… to compete successfully. (Skinner, 1974, p.121)

Fig.1 uses a cloud diagram to illustrates this conflict in D-D' where local optimisation based on cost and efficiency (departmental performance) dominates, resulting in a lack of congruency in meeting the needs of the market. The assumptions underlying B-D is clearly flawed and Skinner's means of resolving this was to separate out these distinct market needs through the concept of a focused factory (Skinner, 1974).

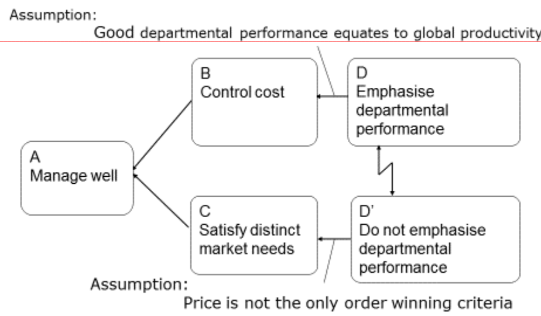

Fig 1 The cloud of operations strategy

Comment [ES1]: Although Cloud diagram may be known wide enough in OM context, adding a reference might not be a bad idea

The focused factory was a natural but significant development from Skinner's earlier work (1969) where he spells out how businesses might bring some congruence back into the factory through ensuring a factory focuses on one key manufacturing task. This paradigm shift in thinking was subsequently embraced by other and notably Hill (1985) who introduced the concept of order winning criteria to link the key manufacturing task more explicitly to the market.

The focused factory approach offers the opportunity to stop compromising each element of the production system in the typical general-purpose, do-all plant which satisfies no strategy, no market, and no task. (Skinner, 1974, p.121)

Skinner's solution was to separate out the delivery systems supporting distinct order winning criteria, so enabling consistent alignment of the trade-off choices, typically within smaller more manageable business units.

Quality - Shewhart

Skinner (1969) identified quality versus cost as one of the classic trade-offs that needed to be aligned which is commonly interpreted in the classic quality verses cost model. However, he subsequently acknowledged the opportunity to mitigate such trade-offs. By the mid 1980's industrial practice in the West was being influenced by exposure to what was termed Total Quality management (TQM).

"When low cost is the goal quality often gets lost. But when quality is the goal, lower costs do usually follow." (Skinner, 1986, p.57)

This view was to be reinforced by the theory of cumulative capabilities (Ferdows and De Meyer, 1990) stating that the first stage in an improvement process is to reduce variability in the product. Fig.2 captures the more specific underlying conflict where D dominates, resulting the optimizing of appraisal and failure costs with inspection providing the means of control.

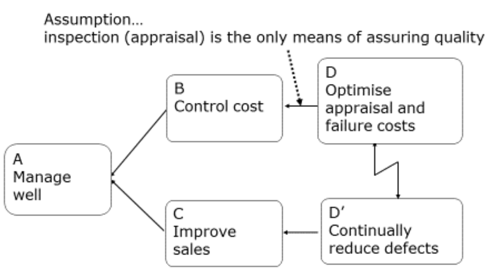

Fig 2 The cloud of operations (Quality)

The resolution of this conflict goes back to the 1920s (Shewhart, 1931) but the wider implications of his seminal work was only realized in the West when the fruit of this quality revolution became apparent (Deming, 1982). Deming was instrumental in communicating this in Japan in the 1950s and in the West in the 1980s but always-acknowledged Shewhart as the originator.

Shewart, working at the Bell Telephone Laboratories in the US, was dealing with volume production and identified the importance of statistics in developing the concept of quality control, which at that time consisted of inspection, typically utilizing 'go' and 'no go' gauges (Shewhart, 1931). From this he developed Statistical Process Control (SPC) as a management signaling tool to enable managers to differentiate variability that was random (common cause) from variation that could be assigned to a special cause.

The challenge was in identifying the assignable as opposed to the common causes of variability and the systematic process of improvement through what is now commonly referred to as the Deming cycle of (PDSA) originally specification-production-inspection.

1. *Our criterion of control should indicate the presence of assignable causes of variation.*
2. *It should not only indicate the presence of assignable causes but also should do this in such a way to facilitate the discovery of these causes.*
3. *It should be as simple as possible and adaptable in a continuing and self-corrective operation of control.*
4. *It should be such that the chance of looking for assignable causes when they are not present does not exceed some predefined value.*
   (Shewhart, 1939; 30)

His work was popularized in Japan in the 1950s and built on by others, some of whom had worked alongside Shewhart included Deming and Juran. Deming (1982) is particularly noted for his philosophical approach to communicating the wider implications of this seminal development. This was summarized through Deming's 14 points and seven deadly diseases all of which can be traced back to the implications of SPC and its practically applied through the SPC charts. This development embraced the importance of management realizing their role in first eliminating the assignable causes and then looking to redesign the process to further reduce the common causes of variation. The traditional view was to balance the trade-off associated with cost and quality with no practical means of involving the workforce in the systematic identification and elimination of assignable causes. The SPC chart provides a signal that can be understood and acted upon at all levels of the organization.

Production flow - Ford

Ford (1926) notably demonstrated the importance of flow in managing a manufacturing system and his seminal innovation is widely acknowledged to be the moving flow line. The model T epitomized Skinner's concept of a key manufacturing task centred on low cost with the choices aligned to minimize variability through standardization, using dedicated processes.

> "*The thing is to* ***keep everything in motion*** *and take the work to the man…"*
> *"If a machine breaks down, a repair squad will be on hand in a few minutes…the* ***machines do not often break down*** *because there is* ***continuous cleaning and repair work …*** *"* (Ford, 1926, p. 103)

The concept of flow was central to his thinking and his system clearly embodied a process of ongoing improvement, driven by the focus on reducing the lead-time and the associated inventory buffers.

> *"Our production cycle is about* ***eighty-one hours*** *from the mine to the finished machine in the freight car"* (Ford, 1926, p. 118)

The concept of systematic waste reduction is also very evident.

> *"Having stock or raw materials or finished stock in excess of requirements is a waste"* (Ford, 1926, p. 99)

It was the moving flow line that provided a mechanism to centralized control ensuring the different parts worked as one, systematically reducing the inventory buffers. However, the success of this approach to synchronizing the delivery system was dependent on volume and the use of dedicated processes and therefore no requirement to manage changeovers. With the retooling needed to introduce the Model A products in 1927 the growing demands for variety exposed the limitations of this control mechanism.

Production flow - Ohno

Ohno (1988), the architect of the Toyota Production System (TPS), makes many references to Ford (1926) and clearly built on Ford's flow concepts but he had the challenge of much lower production volumes. To deal with this, he had to challenge the cost paradigm by refusing to adopt the concept of an economic order quantity, but controversially using available capacity to reduce the need to hold inventory.

> "W*hen a general purpose machine… has excess capacity it is an advantage to reduce the lot size as much as possible aside from the separate problem of shortening setup time.*" (Ohno, 1988, p.56)

Further reduction in the batch size was then driven by reducing the set-up time, often enabling setting up for each product on a daily basis to level out production demands.

"*By the 1960s it [setup time] was down to a mere 3 minutes*" (Ohno, 1988, p39)

This attitude towards buffering with capacity rather than inventory was a characteristic of the TPS enabling capacity to be adjusted to meet demand as an alternative to holding inventory.

> '*The machine-output ratio at Toyota Motors is two or three times that of similar companies. Indeed, for the same level of production,* ***Toyota has far more equipment than other companies*** *and this is one of its strengths.'* (Shingo, 1989: 72)

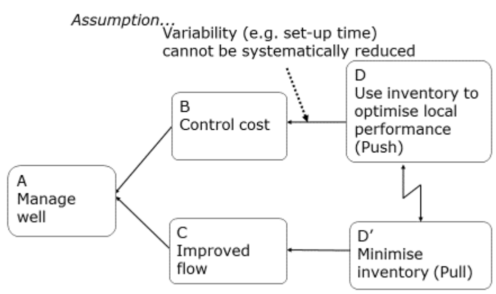

Fig. 3 Cloud of operations (lean flow)

Fig.3 illustrates Ohno's underlying conflict together with the assumption he challenged. Minimising the impact of setups enabled Ohno to imitate Ford's flow approach; however, with the wide variety he needed a different mechanism to manage the flow. Ohno's seminal innovation was the kanban signaling tool.

Kanban is the term Ohno (1988, p27) used to describe the operating method of the TPS.

> *'Kanban is a way to achieve just-in-time; its purpose is just-in-time. Based on this, production workers start work by themselves, and make their own decisions concerning overtime. The kanban system also makes clear what must be done by managers and supervisors. This unquestionably promotes improvement in both work and equipment.'* (Ohno, 1988, p.29)

> *'In reality practicing these rules [the six rules of kanban] means nothing less than adopting the Toyota Production System as the management system of the whole company.'* (Ohno, 1988, p.41)

As with Ford's flow line kanban provided a mechanism to limit material release and facilitates a continual improvement process based on ever improving flow. However, much of the TPS approach to load leveling and setup reduction needs to be in place for it to be operationalized (Shingo, 1989, p.xxvii).

Production flow – Goldratt

Goldratt (1983) more overtly addressed the dysfunctional issues associated with the mass production / cost paradigm, but whereas Kaplan (1984) and Skinner (1986) took a more strategic perspective, Goldratt (1984) was concerned with the specifics of the make-to-order (MTO) environment, which demanded a different solution to that adopted by Ohno (1988).

Batch production dominates this manufacturing environment which was similarly centred on local cost and efficiency, so encouraging high inventory levels, batching and wasteful transaction accounting (See Fig. 4). However, this environment did not so readily lend itself to reorganising around value streams and cells as advocated by the TPS. So, instead of simplifying the physical flows Goldratt (1986) focused on changing the rules and finding a replacement for the cost/efficiency centred measurement system which is now commonly referred to as Throughput Accounting (1984; Noreen and Smith, 1995).

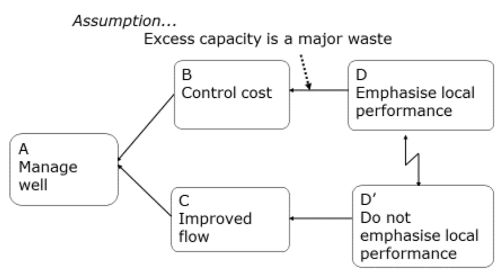

Fig 4 The cloud of operations (TOC flow)

"Almost everyone who has worked in a plant is at least uneasy about the use of cost accounting efficiencies to control our actions. Yet few have challenged this sacred cow directly. Progress in understanding requires that we challenge basic assumptions about how the world is and why it is that way." (Goldratt, 1984, forward)

Goldratt addressed this conflict at a more fundamental level, explicitly challenging the view that '*excess capacity is a major waste*' (Fig. 4). As already mentioned, Ohno clearly substituted capacity buffering for inventory in the process of improving flow and exposing waste. Goldratt took this further in finding a means of more effectively using the buffer capacity in these complex delivery systems. This was achieved by aligning (subordinating) all activities to the constraints whether market or resource. To achieve this aggregated (pooled) buffers are used as a management signalling tool termed Buffer Management (BM). As with Kanban this controls material flow and enables the systematic reduction of sources of variability leading to improved flow. BM is a key concept that Goldratt used in different forms for all his applications, firstly for MTO environments within Drum-Buffer-Rope (DBR) (Goldratt and Fox, 1986) and later project environments within Critical Chain Project Management (CCPM) (Goldratt, 1997).

Findings

Underlying conflict

The paper shows how each development adopted a systems approach that challenged a common conflict underlying the established cost based paradigm. This was explicit in the work of Skinner (1969; 1971; 1974; 1986) and Goldratt, 1983; 1984; 1986) but more implicit in the other two developments. However, both TQM and lean explicitly challenge the trade-off cost models that previously led management thinking and in some texts continue to be used in the traditional format.

Variability and OM laws

Variability is a key phenomenon that in each development provided a basis for systems management. The focused factory concept effectively separated out different levels of variation that drives the trade-offs and the associated focus. This is captured in the laws of trade-off and focus (Fig. 5). The three other developments managed the variability, thereby mitigating the trade-off effect. These developments can be separately allied to the theory of performance frontiers (Schmenner and Swink, 1998). The flow focus of lean and TOC is clearly allied to queuing theory and laws 3-6 in Fig. 5 and at a higher level the theory of swift and even flow (Schmenner and Swink, 1998). It should be noticed that the law of focus reflects Skinner's (1974) and Hill's (1985) focus on the market, but also Goldratt's 5 steps of focusing which embraces both market order winners and resource constraints.

***Law of Trade-offs*:** A delivery system cannot simultaneously provide the highest levels of performance (quality, delivery lead time, delivery reliability, flexibility and cost) (primary attribution: Skinner, 1969).

***Law of Focus*:** A delivery system that is aligned to make the most of a limiting factor (e.g. order winning criteria and bottleneck) will be more productive. (primary attribution: Skinner, 1974; Hill, 1985; Goldratt, 1984)

***Law of Variability*:** Increasing variability always degrades the performance of a delivery system. (Hopp and Spearman, 1996 modified)

***Law of Variability Buffering*:** Variability in a delivery system will be buffered by some combination of Inventory, Capacity and Time. (Hopp and Spearman, 1996 modified)

Law of Bottlenecks: A resource with no buffer capacity dictates the delivery system throughput and provides a focus for planning and control. (Primary attribution: Goldratt, 1984)

Law of Variability Pooling: Combining sources of variability so they can share a common buffer reduces the total amount of buffering required. (Hopp, 2008 modified)

Fig.5 Principles (laws) of operations management (Stratton, 2015)

Seminal management signaling tools

Shewhart, Ford, Ohno and Goldratt developed practical solutions that necessarily embraced a broad range of tools and techniques but what uniquely distinguished them is the underlying signaling tools that provide a coherent means of supporting both alignment and continual improvement. However, due to the different environments the means of achieving this had to be uniquely developed. The opportunity to explore the underlying assumptions further is

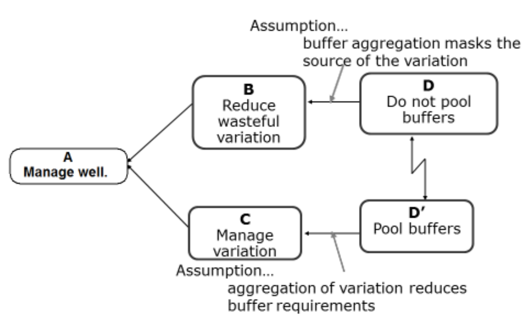

Fig 6 Core assumptions distinguishing Lean and TOC thinking

illustrated in Fig. 6 that shows the assumptions that differentiate kanban from BM. The TPS/Lean is portrayed by A-B-C whereas TOC is A-C-D'. BM is a signaling tool based on the use of aggregated (pooled) buffers, embracing the law of variability pooling (Fig 5) which is in stark contrast to TPS and Kanban. The use of pooled buffers is discouraged in the TPS Kanban system (Spears and Bowen, 1999) due to it obscuring the source of the variability. However, BM can be used much more widely in dealing with complex flow.

Conclusion

Systems thinking is key to managing operations but this is naturally in conflict with the need to manage cost and efficiency at the local level. Therefore, any practical approach needs to incorporate a practical means of aligning activity with the system goal and supporting the continual improvement process. The concept of a focused factory achieves this in part by simplification and separating out the conflicting trade-offs. SPC supports quality management through providing direction and guiding the process of improvement at the process level. Assembly lines, Kanban and BM address the need to manage the flow as well as the improvement process but to meet the needs of very different environments. It is therefore important to consider the assumptions underpinning these tools in developing signaling tools to meet the needs of new environments, such as healthcare and construction. Returning to the initial question concerning the relationship between higher-level theory with TQM and lean. These industrial developments have grown from their seminal origins and it is these that can be allied more readily to the higher-level theory.

Comment [ES2]: These two sentences need to be somehow connected.

Table 1 attempts to summarize the distinctions between these approaches across a range of attributes. The distinguishing laws provide a basis for this association with theories such as the theory of cumulative capabilities, the theory of swift and even flow and the theory of performance frontiers already discussed.

Table 1 summary attributes associated with the OM developments

Attribute	Mfg. Strategy	TQM /Six sigma	Lean	TOC
Environment	Mfg. plants	All processes	Inherently stable flow	Complex flow
Key word	Trade-off	Variation	Flow	Focus
Key assumption	Variability drives strategic choice	Process variability drives quality cost trade-off	Process (batch) variability drives waste	Variability can be strategically managed
Distinguishing Methodology	Product Profiling	Plan, Do, Study, Act	Value Stream Mapping	Causal mapping / conflict resolution (N&S logic)
What to change	Separate out order winning criteria	Specific Processes	Process flow	Management Rules
Distinguishing systems concept	Focused factory	Statistical Process Control	Kanban control	Buffer man'g'm't
Distinguishing Law(s)	Law of trade-offs Law of focus	Law or variability	Law of variability buffering	Law of b't'ks Law of variability pooling

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