Smoothly Pass the Parcel: Implementing the Theory of Swift, Even Flow

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Smoothly Pass the Parcel: Implementing the Theory of Swift, Even Flow

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Abstract

This research examines the application of the Theory of Swift, Even Flow (TSEF) by a distribution company to improve the performance of its processes for parcels. TSEF was deployed by the company after experiencing improvement fatigue and diminishing returns from the time and effort invested. The fatigue was resolved through the deployment of swift, even flow and the adoption of "focused factories". The case study conducted semi-structured interviews, mapped the parcel processes and applied Discrete Event Simulation (DES). From this study we not only documented the value of TSEF as a strategic tool but we also developed insights into the challenges that the firm encountered when utilising the concept. DES confirmed the feasibility of change and its cost savings. This research demonstrates DES as tool for TSEF to stimulate management thinking about productivity.

Keywords Theory of Swift Even Flow; Discrete Event Simulation; Operations Management; Process Improvement

Introduction

This paper focuses on the flow of parcels through a distribution company's processes and the aspects in its operations that impeded throughput. Improving the flow of parcels is more important than ever given the continuing development of internet retailing and the concomitant increase in the volume of parcel shipments. Because of the frequency of delivery and the growth of final destinations, network entropy is increasing. Providing a cost-efficient service under such circumstances is a significant test for any organisation engaged in distribution. This research explores the approach developed by a specific firm and its use of the theory of swift, even flow (TSEF) and Discrete Event Simulation (DES) as a mechanism for improving performance. The authors are not aware of any previous work that attempted to use DES as tool for the TSEF in this context.

Researchers have used the theory of swift, even flow to investigate the flow of patients through healthcare processes (Fredendall et al., 2009; Deveraji, Ow & Kohli., 2013), to understand the performance of service firms over several years (Schmenner, 2004), and to explain why some manufacturing firms outperform their competitors (Schmenner, 2012).

After four years of implementing lean principles with declining success, the case study firm decided to alter its approach by adopting TSEF. The lean campaign involved site-specific improvements that had failed to involve the wider process. This limited the benefits of lean thinking (Hines, Holweg & Rich., 2004). Swift, even flow, on the other hand, enlarged the company's field of vision to include its end-to-end processes and unlocked savings across its organisational boundaries by stimulating the establishment of "focused factories". This shift in point of view required some fundamental changes in management's perspectives of productivity within and across organisational boundaries.

Deploying TSEF provided the researchers with an opportunity to test the concept as an instrument for change, moving the idea from the realms of academia to the practitioners' arena. Two key questions were asked in conducting the investigation: (a) Can TSEF provide a platform for improvement across organisational boundaries, and (b) What mechanisms are available to support the deployments of the TSEF concept as a business level improvement tool?

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The next section introduces a literature review and is followed by a discussion of the case study firm. The methodology used is subsequently explained followed by a discussion of the discrete event simulation that was an important part of the implementation. After that discussion, the results of the implementation of TSEF are presented, and those results are then discussed in more detail.

Literature Review

Schmenner defines the Theory of Swift, Even Flow in this way:

> "The theory of swift, even flow states that two factors – and only two factors – are essential to productivity gain, no matter how one measures them. The first essential factor is to reduce variation. That variation can be of three types: quality, quantities, and timing. That is, one wants (1) to reduce defects and to perfect quality, (2) to even out the varieties of goods produced and the quantities of each so that each day of production resembles every other day of production, and (3) to produce with a regular timing or sequence to production. The second essential factor is to measure the time it takes to produce something from start to finish – its throughput time – and to reduce that throughput time as much as possible. Swift, even flow concentrates its attention on the flow of materials through a process; it asks people to take the viewpoint of the materials moving through a process. By reducing the variation and throughput time of those materials, one eliminates the non-value-added aspects of production, which is where the cost and inefficiencies lie." (Schmenner, 2015, p 345)

Swift, even flow grew out of Schmenner's empirical work on factory productivity internationally. It is a theory that helps to explain how a variety of modern techniques and philosophies work as they do, among them: lean operations, the theory of constraints, Six Sigma, and factory focus (Schmenner, 2012, Chapters 4 and 8). TSEF has been used to explain the huge leaps in productivity that accompanied the creation of the factory, the development of the continuous flow process, the moving assembly line, and other significant milestones in industrial history (Schmenner, 2001, 2012, and 2015).

TSEF does not seek to diminish the power of the landmark lean paradigm (Papadopoulou and Ozbayrak, 2005). Instead, it provides a rationale for lean operations and for other concepts such as factory focus that can affect a company's entire supply chain. A *focused factory* has one (or two) overarching objectives (key manufacturing tasks) that allow an optimised process usually with a narrower range of products. Focused factories can expect to outperform general-purpose production operations (Skinner, 1974, 1986; Schmenner and Swink, 1998). By so doing, TSEF can overcome a common weakness of lean implementation, namely bogging down within individual functions which can limit lean progression and potential (Bamford et al., 2015: Rahbek, Pedersen & Huniche, 2011; Radnor et al., 2006; Bateman and Rich, 2003). Several researchers highlight the potential for lean principles to be a boundary-spanning improvement approach. However, it is also noted that its occurrence as such is rare (Bamford et al., 2015; Scherrer-Rithje, Boyle & Deflorin, 2009; Balle, 2006). Driving improvement based on an enterprise-level process perspective overcomes the limitations of functionally driven, task-orientated, lean approaches that many organisations adopt (Rich and Bateman, 2003; Bamford et al., 2015). TSEF provides management a platform from which to envision and reconfigure the entire process, supporting the organisation in its drive for continuous improvement.

Case Study Firm

The case study firm is a European national distribution business focused on the sorting, distribution and delivery of high-volume parcels, among other items. The organisation is split into regions that operate as hubs for the processing of parcels from local, national, and international customers. Each region contains transportation, sorting and distribution operations. Even though these operations differ in size and complexity, they are linked by a common performance goal of delivering parcels anywhere within the country within 24-48 hours, depending upon the service purchased by the customer. Timeliness of deliveries is critical in terms of customer service.

The Process

The activities within the parcel process are triggered by a continuous stream of arriving trucks to the Operations Hub. Vehicles are unloaded and the parcels are moved into the preparation area where a rough filtering process puts them into trolleys for further processing. The preparation and sorting areas follow a schedule. The volume and timing of incoming parcels exhibit strong variations from day to day. The flow of incoming parcels could not be controlled in this study.

The sorting area at the Operations Hub consists of several identical machines that run in parallel. Parcels are transferred from the preparation area to the machines in such a way that the first machine is filled until it runs at full capacity. Only then are subsequent machines utilised. The machines are continuously filled with items to be sorted according to their destination location. The sequencing stage processes the sorted items in more detail on separate machines so that they can be delivered efficiently to their final destinations. A sequenced batch contains the parcels in the order in which they will be delivered to end customers.

Characterising the Operations Hub and the Distribution Centres

The regional Operations Hub provided each of its Distribution Centres with parcels in two waves (batches). At the Distribution Centres (DCs), the two sequenced batches were merged by hand before being processed further. The regions operated as independent entities that were measured on performance at a local, not a company-wide, level.

The Operations Hub could be characterised as follows:

Mission: To turn the chaos of the arriving parcels into an orderly sequence of parcels that subsequent operations could use to deliver them to their destinations. The Operations Hub under study fed 20 Distribution Centres.

Metrics: The major metrics used were “items per hour per machine” and “workers per machine”.

Issues: Because of these metrics, the incentive was to keep the sorting and sequencing machines busy and to always process all of the parcels that had been received that day. This is why the Operations Hub provided each of the 20 Distribution Centres with parcels in two waves (batches).

Each Distribution Centre could be characterised in similar fashion:

Mission: To take the output of the Operations Hub and to sort the parcels into smaller batches for delivery by hundreds of delivery vehicles.

Metrics: How quickly the delivery people can get their individual batches ready for delivery.

Issues: Because the Operations Hub fed each Distribution Centre twice during the day, the delivery people had to merge the two batches by hand. This involved a lot of work and considerable space so that the final delivery sequence could be accomplished accurately. Delivery could not proceed until both waves of parcels were merged at the Distribution Centre. In essence, the Distribution Centre was forced to engage in sorting and sequencing itself.

History of Improvement Initiatives

For four years, the company had used a Japanese lean operations consultant and had deployed lean tools to make improvements to its operations at the major, sorting hub under study (Figure 1) (MIT, 2000). The approach initially provided increases in labour productivity and equipment utilisation. However, early gains over the four-year period were not maintained, with overall equipment effectiveness (OEE) increasing initially by 3% and then falling back to 0.5% as the lean campaign continued.

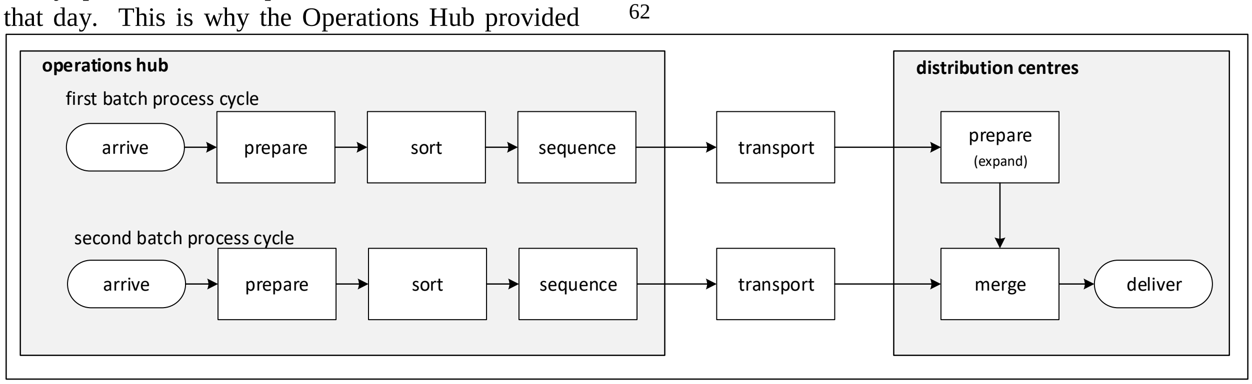


Figure 1 Process flow schematic (as-is scenario).

The company’s approach to improvement focused on its Operations Hub and not on its entire company-wide operations. Such an approach is commonly deployed by organisations engaged in a lean campaign (Bicheno, 2008). Although implementing lean into parts of a process is a pragmatic and common occurrence (Bamford et al., 2015), reducing the supply chain and its processes into its constituent parts, instead of taking an end-to-end process perspective, can obscure the causes of problems (Checkland, 1981; Simons and Taylor, 2007). The partial implementation of lean thinking within the company's functional silos had not engendered a lean philosophy across the entire business. Instead, it created islands of excellence (Hines, Holweg & Rich, 2004). Such localization has been found to diminish the ability of organisations to sustain improvements (Gurumurthy and Kodali, 2011). The financial benefits delivered by the case study company's lean improvement approach had begun to dwindle over the four-year period, leading to questions about the sustainability and purpose of continuing.

Recently, the company has been undergoing a series of modernisation activities due to a change in its ownership. This change in ownership prompted the firm to step up its improvement efforts. The first area selected for company-wide improvement was the distribution of small parcels. This project provided the opportunity for improvement covering sorting, transportation and distribution. End-to-end process changes across functional silos were recognised as offering potentially significant increases in cost and service performance. The operating hub and distribution centre management teams, which remained unchanged following the ownership, were eager to address the limitations of localised area improvements and to move forward.

The researchers had initially been invited by the case study firm to investigate the organisation's approach to improvement after the lean campaign had begun to deliver diminishing returns. After discussions with senior executives, it became apparent that something more was needed to help the firm move forward with its continuous improvement initiatives. The management team was introduced to the concept of swift, even flow and they read Schmenner's 2012 book.

Upon learning about swift, even flow and asking themselves the questions of where variation exists in the process and where throughput time bogs down, the company's managers hypothesised that there could be savings in transportation and handling costs by condensing the two process waves into one. They envisioned different strategic "missions" for the Operations Hub and each Distribution Centre. The Operations Hub's product would no longer be "waves" of sorted packages but a single sequenced daily batch of them. This batch would become the single input for each Distribution Centre. The Distribution Centres would no longer have to merge the batches together. This simplified the missions for both operations. Management realised as well that the metrics they had used for each location and the incentives that those metrics fostered had to be changed to unleash the potential of the organisation (Skinner, 1986). In academic parlance, two "focused factories" would be created in place of the more chaotic, overlapping situation that had prevailed.

Once this strategic insight was agreed upon, the managers' concern was whether the Operation Hub's capacity would be sufficient to process all parcels in a single batch. Changes in the initial sorting operation were expected to show up as financial gains in the subsequent transportation and distribution operations. This represented a marked change in approach as it would cross functional boundaries and require cross-party co-operation, an essential, strategic issue that the company's lean campaign had not addressed. Management would have to consider the flow of information and product across their sites to deliver the benefit. Doing so can be challenging because applying new approaches across organisational boundaries can result in resistance by employees (Schilling and Kluge, 2009).

We readily acknowledge that a different consultant could possibly have advocated for the same action plan that is reported in this article. Nevertheless, an experienced Japanese lean operations consultant, in work spaced over four years, missed the opportunity that we recognised almost immediately using the theory of swift, even flow. It has been said that there is nothing as useful as a good theory, and, for us, this case study provides another supporting example. This paper does not doubt the powerful track record of lean but the firm had failed to progress with its lean approach (Bamford et al., 2015). However, the research emphasis here is on the usefulness of TSEF to provide a platform for change, including the strategic change embodied in the focused factory concept.

Methodology

Case study research supports "empirical research that primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon" (Barratt, Choi & Li, 2011, p 329). Utilising a case study approach for deductive, theory-testing purposes within operations management has been found to be a fruitful methodological approach (Meredith, 1998; Voss, Tsikriktsis & Frohlich, 2002; Bitektine, 2008). However, this case study research is not exclusively deductive in nature. While TSEF provided the basic logic for the research questions posed, the data analysis and empirical findings exhibited inductive features. As Ketokivi and Choi (2014:235) explain in their review of case study research "theory-testing is driven by theoretical deduction, but not exclusively limited to it".

The case study research design combined a quantitative and qualitative approach to gathering and analysing data (Yin, 2003). Gathering a mix of quantitative and qualitative data enabled the research team to obtain a good understanding of the operation (Staats, Brunner & Upton, 2011; Narasimhan, 2014) and a "synergistic view of evidence" gathered (Eisenhardt, 1989: p533). On the quantitative side, varied data collection methods provided strong substantiation of the theoretical model. Furthermore, three investigators were deployed, strengthening the confidence and credibility of the findings (Eisenhardt, 1989; Barratt et al., 2011). Case selection is a critical step in case study research as it focuses the efforts of the investigators. Cases should be chosen which aid researchers to "replicate or extend the emergent theory" (Eisenhardt, 1989: p537). Through examining TSEF within a case study the researchers had the opportunity to examine the concept as business improvement approach. The details and criteria used to select the chosen case are as follows:

- It had actively pursued variability reduction in its processes. The organisation had worked with lean tools and techniques, such as TQM, SPC, TPM and 5S, for four years to minimise process variation against a background of high volatility in customer demand.
- It demonstrated an interest in improving its throughput time and therefore flow in its processes.
- Through the mapping of the process and the development of simulations and animations to visualise flow, the business itself identified opportunities for improvement.
- The case study company, as a result of changes in ownership, had begun to look at altering the flow of parcels across functional boundaries to gain end-to-end supply chain benefits instead of pursuing a traditional silo approach. With this change in its point of view, the company could potentially overcome the limitations of its "islands of excellence" experience from its application of lean principles (Bamford *et al.*, 2013).
- It was willing to execute changes as a result of the research so that the researchers could observe changes to the processes and organisation as they unfolded.

Qualitative Aspects

Data were collected through a multiple-method approach including semi- structured interviews, observations and internal document reviews. Interviews were conducted with 16 people ranging from senior group executives to front line operators, across the Operations Hub and the Distribution Centres (see Table 1 for details). Information on the views of the participants as well as data on changes in performance due to the application of TSEF and factory focus were collected from observations made at meetings and as the process was altered.

Quarterly review meetings were conducted with the steering committee in charge of implementing the changes. These meetings provided project updates as well as insights into technical and organisational issues. Senior management progress presentations permitted the project team to update management on progress and obstacles to implementation. These sessions helped to develop a standardised approach for the future implementation of TSEF and factory focus across other regions and sites.

These feedback sessions also provided an opportunity to triangulate our findings with the people managing and operating the processes, providing internal validity (Fredendall et al., 2009). Following interviews, meetings and observations, the research team met to discuss and consider the challenges and successes that the organisation was experiencing. These post-meeting sessions allowed the researchers to work together to reach a consensus view of the progress and issues faced by the company.

Table 1 **Interview details.**

Role(s)	Duration and frequency
Hub Management (including operations director, quality manager, improvement manager and logistics manager)	Interviewed between 60 - 90 minutes before and post TSEF implementation
DC Manager	Interviewed for 45 minutes before and 30

	minutes post TSEF implementation
Hub shift supervisors (two), logistics supervisor and operators (one despatch operator and two parcel operators)	Interviewed between 20-45 minutes before and post TSEF implementation
DC operators (two)	Interviewed between 15-20 minutes before and post TSEF implementation
Group Management (Head of Design, Technical and Logistics)	Each interviewed for between 40-50 minutes post TSEF Implementation

Quantitative Aspects

Although the case study company's managers were open to the application of TSEF to their operations, some of them still needed convincing. Therefore it was decided to embark on several quantitative exercises that could help the managers envision what the adoption of swift, even flow and focused factories could mean for them. To that end, data were collected directly from the case study firm and from researcher measurements and observations. Historical data covering a two-year period were gathered and analysed. Of particular interest were data on:

1. Demand – the delivery profile from day to day
2. Quality – waste reduction, quality levels
3. Bottlenecks – machine capacities, throughput rates, capacity constraints, and utilisation
4. Scheduling and resource planning
5. Variability – volumes, transport times, operations times

Staats, Brunner & Upton (2011: p380) suggest that before investigating future changes it is important to identify the previous "initiative's empirical performance" in a quantitative manner. Data was collected and assessed for reliability and accuracy. For example, efficiencies and utilisation were tested through observation and measurement by the researchers. Although the recorded output data were found to be accurate, the standards used to gauge performance were found to be at variance with the machine manufacturers' published data. Machines were found to be "slow running" and agreed performance standards were below the potential of the process, leading to inflated efficiency figures. These data provided the research team with an understanding of "true" performance changes due to improving flow and reducing variances. The overall case study has the following sequence: Case selected; Protocol & Data collection; Data Analysis (simulation); TSEF Pilot & Data collection; Discrete Event Simulation; Answering research questions; Literature comparison, and Research closure.

Discrete Event Simulation

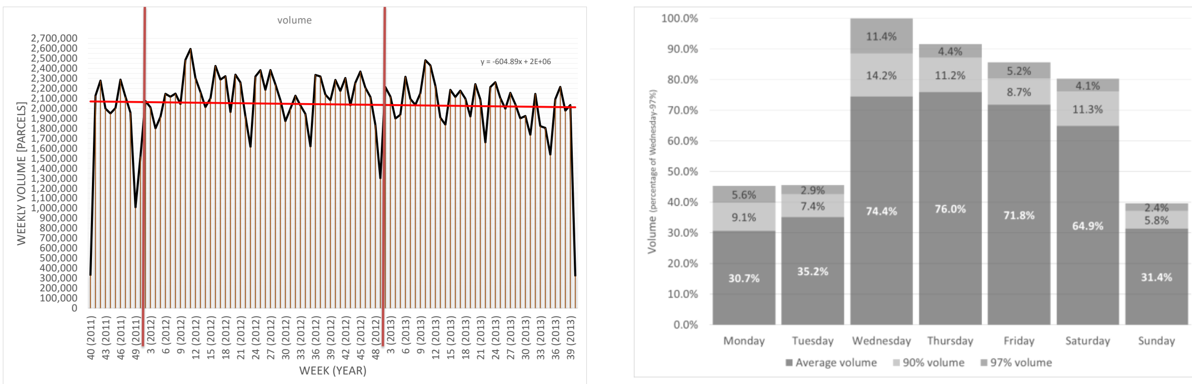
The goal of the simulation was to compare the current (as-is) model with the proposed (to-be) scenario so that the company's managers can see the advantages to the perspective taken by the theory of swift, even flow. The as-is structure is shown in Figure 1 and the to-be scenario is depicted in Figure 6. Specifically the aim was to quantify the reduction of labour and the value-added process time. Furthermore, the effects on variation by removing the second process cycle can be observed.

The simulation design follows the classical phases. That means first input data for the simulation was collected. This data was used to determine arrival rates, throughput rates and capacities for each process stage. Probability distributions were fitted accordingly. The simulation was realised using a discrete event simulator, specifically the Rockwell Arena simulator. (A technical appendix is available from the authors). Each process stage was verified independently. The simulation structure and results were validated by subject matter experts. This was done for each process stage and the entire process chain. The design of the experiments took into account sufficient variations of input, output and resources. Multiple replications were used to increase the confidence of the results.

In order to configure the simulation models appropriately, all essential process stages (see Figure 1) have to be analysed. The overall demand of parcels, which is the input and output, is the driver of the whole process. Thus, an understanding and quantification is the first step in the analysis (section 5.1). The arrival of the "parcels" via trucks is explained in more detail (section 5.2). The flow of parcels through the various process stages in the "as-is" scenario is specified and shown in section 5.3 and 5.4. These sections explain the technical details and measurements. In section 5.5 a particular emphasis is given to the timings. The timings suggest the feasibility of combining duplicated process stages (cycles). This is confirmed with the "to-be" simulation scenario (section 5.6). Furthermore this improved process flow leads to cost savings.

Incoming Demand and Daily Profiles

The number of items received by the sorting centre on a daily basis was recorded over a period of almost two years (98 weeks). The weekly volume was 2.04 million parcels, on average. A linear trend analysis indicated a year-to-year decline in parcel volume of about 2.1% (see Figure 2(a)). The weekday profile is shown in Figure 2 (b).



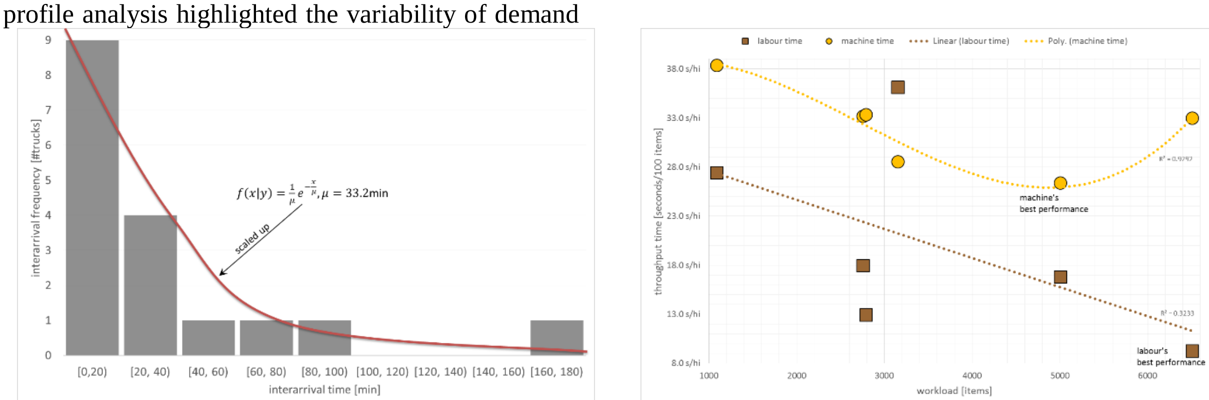
(a) (b)

Figure 2 (a) Demand/weekly volume time series; (b) weekday profile.

The figure highlights that Wednesday is the "heaviest" day. Therefore, special attention was given to that day and all weekdays were normalised based on its 97% quantile expected volume. A 3% service-level violation on the heaviest day was seen as more than acceptable by the practitioners. That means we expected that 97% of all Wednesdays would have a volume that is less than 525,979 parcels. On average, a Wednesday has 411,689 parcels (normally distributed with standard deviation of 75,123 parcels). In order to get an idea about service-level volumes we determined the 90% and 97% quantile parcel volumes per weekday in addition to the average volume. The 90% quantile parcel volume was directly derived from the sample of 98 weeks, whilst the 97% quantile was based on a normal distribution assumption. Given the above Wednesday data, other absolute quantities can be derived. For instance Tuesday's average volume is 35.2% × 525,979 parcels = 194,649 parcels. The profile analysis highlighted the variability of demand in terms of weekdays and arrival times. It showed that if there was sufficient capacity in the sorting centre and distribution centres to deal with Wednesday demands, then the other weekdays could be accommodated as well. It can be seen that a potential solution to improve the flow of parcels through the process chain would have to be able to operate under significant variances in demand across the week. The nature of the demand suggests that the operation can be designed as a pull system (Heizer and Render, 2011:656). A strategy of levelling out the daily demand variations cannot be implemented due to the company's service agreements.

Incoming Parcel Arrival Stream

The above volume is delivered to the sorting centre via trucks with varying loads. Inter-arrival patterns of trucks are shown in Figure 3 (a).



(a) (b)

Figure 3 (a) Inter-arrival time distribution of trucks; (b) sequencing labour and machine throughput times.

The 17 observations took place between 18:40 pm until 4:05 am and were confirmed via 9 weekly repetitions. It was assumed that the obtained pattern was representative for each Wednesday and could be extended to a 24-hour time frame. An exponential distribution was fitted to the data, giving a maximum likelihood estimate of 33.2 minutes for the mean. Thus, we expected 43.4 trucks (using Little's Law $N = \lambda T$) over a 24-hour period to carry an average load of 412,000 parcels. A truck carries on average 9,492 parcels with a standard deviation of 1,732 parcels (normally distributed, derived from the overall demand and the 9 observational repetitions).

Throughput Rates and Capacity

The *throughput rate* is defined as the number of items that are processed to completion during a specified time period. The *nominal (design) capacity* is the maximum achievable throughput rate under ideal workload conditions. The *usable (effective) capacity* is the average achievable throughput rate under "typical" (high) workload conditions. Here, the *service rate* will be defined as the usable capacity. The *utilisation* is defined as actual throughput as a percent of nominal capacity. *Efficiency* is the actual throughput as percent of usable capacity.

The firm investigated the application of TSEF to its Operations Hub and Distribution Centres specifically to reduce variation and improve throughput time. To this end, the throughput rate for each process stage was measured. The challenge here was the conversion of different batch units, i.e., finding the "smallest" common entity. In the beginning the units of arrivals are truckloads. These units are transformed into trolleys, followed by items, for analytical considerations. The analytical considerations were primarily based on throughput rates (λ), volume (N) and time (T). The relation of these measures can be expressed using Little's Law:

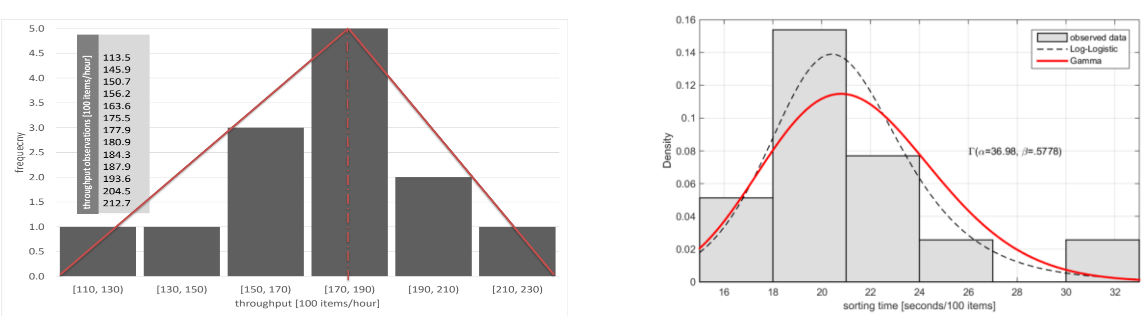
$$N = \lambda T. \qquad (1)$$

The throughput rates for all process steps were determined. The analysis of available and necessary times for each process step showed that sequencing was the critical process step because the machines can only start once the items have been sorted. Interestingly, this is due to the nature of the process rather than its performance.

Throughput rates for all process steps were determined based on actual observations rather than the machines' specified maximum throughput rates. As indicated in the above definitions the provided workload at each process stage (i.e. fill factor of buffers/queues) is essential for the actual throughput. That means random arrivals at a process stage without sufficiently filled item buffers lead to significant drops in the throughput rate.

Sorting, Sequencing and Merging Process Stage Characteristics

Several sorting machines (4 to 6, average: 4.85) were observed. This includes the operating personnel. Thirteen observations were done made over a period of 87 days. Each observation analysed a planned run of five hours. Figure 4 (a) displays the operational throughput rate observations.



(a) (b)

Figure 4 (a) Observed throughput for sorting; (b) fitted sorting time.

The variability is mainly due to human interaction in the feeding process or when removing full cage trolleys. A gamma distribution with parameters α = 36.98 and β = 0.5778 with a log-likelihood of -34.7 was fitted to describe the service times (Figure 4 (b)). This leads to an average sorting machine throughput of λ = 15,157 items/hour with an average total processing time of 5.51 hours for all five machines. The overall throughput rate for sequencing varied between 5,475 items/hour and 8,536 items/hour per machine. Figure 3 (b) shows corresponding labour (preparation and destack time) and machine (three passes) throughput times, for the sequencing stage, in relation to the workload (volume of parcels).

This indicates that a higher volume of parcels can be prepared by human resources than is required in the subsequent machine stage. Labour's service time was approximated by fitting an exponential distribution with mean 11.1 seconds plus a 9-second offset. The machine performance depends on the workload and is shown in Figure 3 (b). The machines' best performance (26.4 seconds for 100 items) was used as the nominal capacity (assuming ideal workload). Furthermore, this capacity will be used to describe the machine's maximum service rate. The workforce required to feed the machines has a higher throughput rate than the machines (Figure 3 (b)) indicating possible resource savings and a further reduction in process speed variations.

The merging process stage takes place in the distribution centres. The directive is that a person should process (merge) 32 items per minute. However, the actual observations showed that a worker has an average throughput of 11.3 items per minute. Non-standard and variable approaches to executing the sequencing tasks were found to diminish the throughput rate. For example, operators would operate differently in terms of preparation for merging. Some would organise their parcels to be closer to the work station before work commences whilst others would prefer to walk between the loading bays to collect their parcels during the merging period. In total, 515 workers are available in all the distribution centres. Table 2 summarises the found service time probability distributions of the entire process chain.

Table 2 Service time/rate probability distributions of essential process stages.

Process stage	distribution	p1	p2	p3	unit	Arena expression
Daily volume	normal	μ = 4116.9	σ = 751.2		100 parcels / day	
Truck arrivals	exponential	λ = 33.2			minutes / truck	EXPO(33.2)
Load per truck	normal	μ = 94.92	σ = 17.32		100 parcels / truck	NORM(94.92,17.32)
preparation	uniform	a = 3.375	b = 4.125		seconds / 100 parcels	UNIF(3.375 , 4.125)
sorting rate	triangular	a = 113	c = 180	b = 213	100 parcels / hour	
sorting time	gamma	α = 36.98	β = 0.578		seconds / 100 parcels	GAMM(36.98, 0.5778)
seq. time - labour	exponential	λ = 11.1		c = 9	seconds / 100 parcels	9 + EXPO(11.1)
seq. time - machines	constant	c = 26.4			seconds / 100 parcels	26.4
transport	uniform	a = 20	b = 40		minutes / 100 parcels	UNIF(20, 40)
merging	normal	μ = 9.1	σ = 1.82		minutes / 100 parcels	NORM(9.1, 1.82)

Timings and Process Flow

Figure 5 shows the essential activities and their respective timings for the two batch process cycles. Transitions between activity-timelines involve storage and movement. As explained above, a truck arrives on average every 33.2 minutes (varying arrivals and workloads). The first truck arrives at 4 am, arrivals continue until the cut-off time 8 pm. The time window [4 am, 8 pm] of 16 hours defines the first batch. Once it is 8 pm the volume for batch 1 is known. The second batch run covers the remaining 8 hours and completes a full daily cycle irrespective of the day of the week. At 4 am the actual volume for the day is known (see Figure 5). The received items are unloaded and prepared in a dedicated area. The systematic preparation is discontinued at 1 pm and substituted with an ad-hoc preparation at the sorting machines.

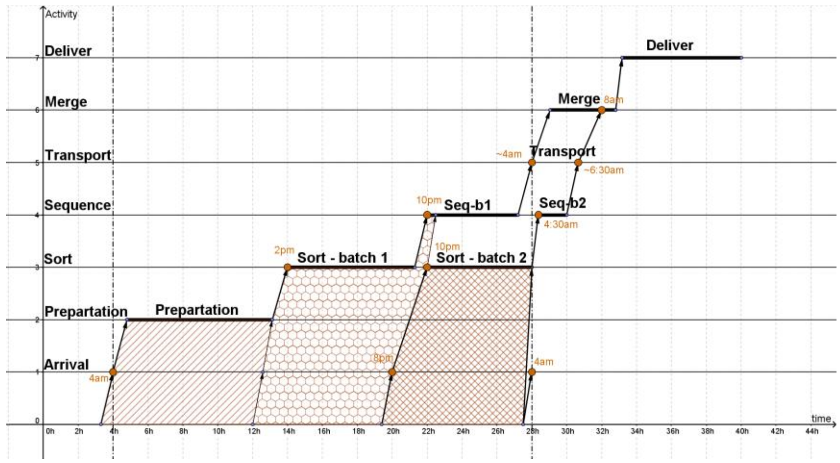


Figure 5 Time-activity diagram.

The sorting process starts at 2 pm and stops at 10 pm. Here, a complication can occur when items cannot be fed into the sorting machines. Usually these are small amounts which are dealt with manually before sequencing starts. The criteria used to start the sequencing process varied occasionally and was based on utilisation of workers and the capacity of the equipment. Success for the area was assessed on the overall equipment efficiency per machine based on running time and labour efficiency, not the achievement of the schedule, which was a plant level measure. This view mistakenly thinks that labour efficiency is indicative of productivity (Skinner, 1986; Schmenner, 1991 and 2015)

The sequencing stage for small parcels operates as a batch operation. The sequencing machine group was identified in the study as a bottleneck in the supply chain and therefore a limitation to increasing the throughput of the machines. The researchers observed that certain machines were operating at full capacity intermittently whilst others ran at a lower level consistently. Some operators would fully load the equipment for short periods of time and then leave the area to collect further parcels or have unplanned rest breaks. Others would ensure that sufficient workload was available on-going to support a constant volume over the allocated period of time. Both approaches, reminiscent of the tortoise and hare fable, eventually produced the planned output. The observations highlighted the non-standardised work procedures across the area. Issues of employees failing to adhere to standard operating procedures, therefore diminishing the power of lean, were a common occurrence.

The sequencing stage is followed by a transportation activity, where trucks distribute the items to the corresponding distribution centres. Here, a fleet of 20 trucks and drivers were used. Travel times varied with an average duration of approximately 30 minutes. These transportation journeys start at 5 am for batch 1 and at 8 am for batch 2. In the distribution centres the merging occurs with an aggregated workforce of 515 people. The planned durations are 45 minutes and 30 minutes for batch 1 and 2 respectively. Table 3 summarises all the activities and their duration characteristics. It also shows the associated resources and costs.

Table 3 Durations, resources and costs per activity.

			duration			resources		planned cost			simulated busy cost		
activity	batch	start	plan	sim.	diff.	PR	HR	total	PR	HR	PR	HR	diff.
arrival & prepare	batch 1	04:00	16.00	16.00	-	-	3	720	-	720		66	1,014
	batch 2	20:00	8.00	8.00	-	-	3	360	-	360			
sort	batch 1	14:00	7.00	5.61	1.39	5	5	1,295	770	525	555	378	1,379
	batch 2	22:00	5.50	5.51	- 0.01	5	5	1,018	605	413			
sequence	batch 1	22:00	5.00	4.01	0.99	6	6	1,110	660	450	686	356	401
	batch 2	04:30	1.50	1.70	- 0.20	6	6	333	198	135			
transport	batch 1	04:00	0.50	0.48	0.02	20	20	370	220	150	424	289	27
	batch 2	06:30	0.50	0.48	0.02	20	20	370	220	150			
merging	batch 1	05:00	0.75	0.98	- 0.23	-	515	5,794	-	5,794	9,669		- 13
	batch 2	08:00	0.50	0.55	- 0.05	-	515	3,863	-	3,863			
delivery	all	09:00					515	-	-	-			
	total	*29*	*45.3*	*43.3*	*1.9*			*15,232*	*2,673*	*12,559*	*11,334*	*1,090*	*2,808*

The resources are divided into physical resources (PR) and human resources (HR). The number of available (or assigned) physical and human resources are abbreviated with n_p and n_h respectively. For instance the transport activity from the operations hub to the distribution centres requires n_p = 20 trucks and n_h = 20 drivers. The planned cost for using 20 trucks for half-an-hour is determined by \$22/h ×0.5h ×20 trucks = \$220. Roughly spoken the busy cost is the product of resource cost, busy time and number of busy resources. A more precise formulation is

$$\sum_{\Delta t \in T} c \cdot \Delta t \qquad (2)$$

Where Δt is the time interval a resource is used for servicing, c is the cost for using the resource and T is the set of all time intervals (which can overlap). The simulated busy cost is the busy cost but with Δt used from the simulation (abbreviated with Δt_s) Note that:

$$\sum \Delta t_s < (d_{s1} + d_{s2})(n_p + n_h) \qquad (3)$$

Where d_{si} is the duration obtained by the simulation for batch i.

The previous sub-sections have given a detailed explanation of the current scenario, and raise the question: Is it possible to combine the batch 1 and 2 operations?

To-Be Scenario

This sub-section will show that sufficient resources are available to allow a single batch run. The To-Be scenario (Figure 6) simplifies the As-Is scenario (Figure 1) by combining the two batches.

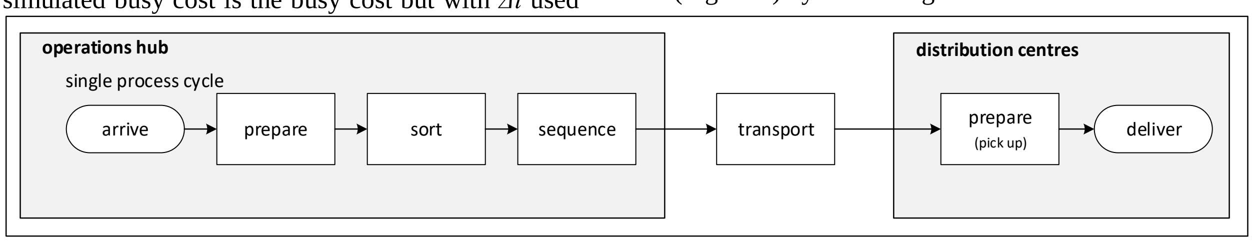


Figure 6 Optimised process flow (to-be scenario).

The perceived bottleneck in the area was not machine capacity but scheduling. Labour would be scheduled to move between sequencing equipment and another area of the plant to balance the workloads across the different areas. The logic behind this approach was explained by the shift manager as a “balancing act.” While the small parcel area waited for the next batch to build-up the operators could be gainfully employed working in another part of the business to ensure high labour efficiencies. “We work in two cycles as this is a more efficient use of labour. While we wait for the next batch to build-up we move labour to do prep. work in the large parcels area,” stated a supervisor. However, the perceived “efficient” use of labour did not improve the throughput time for sequencing small parcels. Focusing on and improving labour and equipment efficiencies, had no impact on the overall throughput time of the process and its potential competitive advantage (Skinner, 1986).

The to-be scenario details are shown in Table 4. The activities are a subset from the as-is scenario. They range from the arrival & preparation of parcels to delivering them.

Table 4 Results of simulated to-be scenario.

		duration			resources		planned cost			simulated busy cost		
activity	**start**	**plan**	**sim.**	**diff.**	**PR**	**HR**	**total**	**PR**	**HR**	**PR**	**HR**	**diff.**
arrival & prepare	04:00	24.00	24.00	-	-	3	1,080	-	1,080		66	1,014
sort	15:30	11.12	12.08	- 0.96	5	5	2,057	1,223	834	544	371	1,143
sequence	02:40	5.71	5.62	0.09	6	6	1,268	754	514	670	349	248
transport	08:05	0.48	0.48	0.00	20	20	355	211	144	210	143	2
pick-up	08:35	0.19	0.19	0.00	-	515	1,468	-	1,468	1,211		257
delivery	09:00					515	-	-	-			
total	*29*	*41.5*	*42.4*	*- 0.9*			*6,228*	*2,188*	*4,040*	*2,634*	*929*	*2,664*

It can be seen that activity durations overlap, which supports the importance of using simulation rather than average value calculations. In this scenario the arrival & preparation at the operations hub is continuous over a period of a complete day cycle (24 hours) rather than being split up into a 16 hours and 8 hours batch (as done in the as-is scenario). In order to find appropriate activity start times of operations and transportations, the latest allowed delivery time (9am) at the distribution centre is the starting point for calculations. The expected durations (in above table "plan" columns) are obtained by using the throughput rates found in the previous subsections. Back tracking these duration lead to the specified start times. Simulations allow further refinements of the anticipated durations, because of their ability to consider the whole process chain's random behaviour (variations). The averages from multiple simulation runs were used in the "sim" column. Another advantage of DES is the availability of resulting probability distributions for service level considerations. It is recommended to use those values rather than the "plan" values. For instance it can be seen that the simulated sorting duration is about an hour longer than the planned duration, which is a more reliable measure. Although the overall duration of the to-be scenario is similar to the as-is scenario (2.2% difference). The cost savings are substantial. The planned cost savings are 59.1% using the to-be scenario ($6.2k/day) rather than the as-is scenario ($15.2k/day). The planned costs assume that the personnel has to be paid even when resources are not adding value. The busy cost focus on the value added services only. The busy cost (value added) savings are 71.3%. Closer investigation of the tables reveal that these savings were mainly due to removing the excessive labour cost that was caused through the manual merging process.

The unevenness of flow in the small parcel area was as a result of resource planning, labour and machine utilisation, and non-standardised work practices, not machine capacity. By running in two batches, management optimised machine running efficiency and delivered against their KPIs for utilisation. This also meant that the sequencing operation, due to sufficient buffer capacity (time), did not lead to any blockage in the preceding upstream process steps. The downstream supply chain, however, experienced "starvation". The manual merge area at the Distribution Centre received parcels in two batches. This meant that unloading vehicles and handling product would occur twice. The first batch would be unloaded and reside in the merge area until the second delivery of parcels arrived. This led to space problems, particularly around peak periods such as Black Friday and Christmas, as operators would have to manoeuvre around their work-in-progress parcels until such time that they could execute the merging activity.

Smoothing the flow of work through the sequencing area was expected to provide a continuous volume of product across the supply chain. This was expected to reduce transport costs between the operations and to result in fewer process delays and less duplicate handling and unnecessary motion. However, achieving these benefits would require a change in not only the planning of resources across the supply chain but also the key performance indicators (KPIs) used to drive performance. In order to achieve the support required, the project team mapped and analysed the processes leading to the development of simulations and animations to explain and show the potential benefits of the changes.

Implementation Results

The data analysis and simulation demonstrated to the case study firm that forming two focused factories and condensing the two cycles of parcel sorting was both feasible and desirable, reducing waiting time in the process and smoothing the flow. The design/dimensioning of the process was based on a 97% service level (see Figure 2). And, because of the forecasted reduction in future volumes, the service level will be even higher in the future. The important aspect to consider was the runtime of the sequencing step, which can be derived from Little's Law using the throughputs from Table 1. The average throughput rate was 7,128 items/hour per sequencing machine, a rate sufficient to handle most periods. This visualisation of the process led to the decision to proceed with the project and implement the principles of TSEF.

Given this analysis, the two sequence cycles were combined, leading to cost savings in transport and labour between the Operations Hub and the Distribution Centres. ***The significant cost reduction was located in the Distribution Centre (over 90%) whilst most of the changes in process and working practices occurred in the Operations Hub.*** Smoothing the flow across 12.5 hours by removing the batching approach to sequencing resulted in the eradication of the merging activity in the Distribution Centre and reduced transport movements.

Through piloting the new way of working the savings demonstrated by the simulation (Table 4) were beginning to be realised. However, they were not fully matured before our study finished. Savings as expected were mainly due to removing the excessive labour cost that was caused through the manual merging process. Furthermore, the condensing of the two batch cycles into a single even flow annualised savings of 106,000 travelled kilometres and a saved travel time of 2,117 hours, based on the pilot, for the Distribution Centres was being projected. Labour savings due to the change in flow were significant, resulting in a redistribution and refocus of labour to improve the service offering and frequency of deliveries to major population centres. Thompson (1992) showed that controllable work improves the labour utilisation, which was confirmed during this project. Furthermore, rejected parcels from the Operations Hub that were manually handled by the Distribution Centres were reduced by 1.5% in terms of volume, leading to additional savings. Minimisation of rework improved the flow of parcels through the supply chain and reduced the effort required to handle them as operational failures diminished. Operators recorded a reduction of over 60% in time wasted travelling between goods-in and final despatch.

Discussion

These empirically-grounded findings show that the application of TSEF and "focused factories" can indeed improve the performance of a services-based organisation. To make it work, however, several inhibitors to reducing variation and throughput time improvement had to be overcome. In this section, we address those inhibitors: (i) silos, (ii) inappropriate performance measures, (iii) lack of vision, and (iv) sources of variation.

Toppling Silos. One of the major impediments to developing a TSEF approach was the organisational structure that existed within the case study firm. Historically, managers devoted attention to their immediate area of responsibility. Such a silo perspective limited understanding of the enterprise-wide improvements that could be implemented (Akkermans and Voss, 2013; Bamford et al., 2015). Functional orientations reduced both the flow of information and the end-to-end process data that could be used to optimise the flow of value across the organisation. Silos also minimise internal coordination and that hinders the ability of a firm to manage demand fluctuations (Ellram, Tate & Billington, 2004). This silo problem surfaced in this case with the cancellation of several meetings between the TSEF project team and the DC. The director had to intervene. "Resistance from managers there [DC] delayed the implementation. Once we could explain and show the benefits, this improved. We're just not used to talking about working together to make improvements", explained one project leader from the Operations Hub. Reducing organisational barriers and developing an end-to-end perspective that can drive flow across functional boundaries was critical to implementing TSEF.

The change in ownership created the impetus for improving flow and developing an inter-organisational improvement perspective. Harmonising activities end-to-end improved the decision making within the entire organisation. Skinner (1986:p56) highlighted the importance of altering the "approaches in materials and work force management" as critical to unlocking the competitive advantage of a factory. Cross-site teams were established to support the enhanced communications and information sharing across supply chain boundaries. "Creating a single batch run will deliver substantial savings across the pipeline of our entire business," stated the head of design for the group. The management of the company recognised that current work practices and governance structures could be limiting the organisation's opportunities. This aligns with the argument of Bamford et al. (2015) on the development of lean that full adoption of the concept requires the removal of "restrictions and blockages in order to progress". By adopting TSEF and building upon the benefits of previous lean projects, management enabled company-wide improvements to be made.

Overcoming Inappropriate Performance Measures. Altering the flow across the company required the case study firm to create new metrics because the historical approach, which had been the foundation for improvement, was no longer appropriate. Operationally, the case study firm had concentrated on increasing efficiency when the machines ran by maximising loading for discrete and unconnected periods of time. This surging approach was driven by KPIs such as Overall Equipment Effectiveness (OEE) and labour efficiencies which measured output when the machine ran. The weaknesses of a productivity approach that focuses tightly on the efficiency of workers through the application of more stringent controls "detracts attention from the structure of the production system itself". (Skinner, 1986:56) Achieving improvements in the evenness of flow requires management to focus on measures of variability and throughput time reduction, not labour and machine efficiencies (Deveraji, Ow & Kohli, 2013). Our findings align with the view of Schmenner (2012) and Skinner (1986) that measures of performance are important however they can be misleading if not used to drive appropriate supply chain and factory improvements.

Moving beyond the modus operandi of incremental lean improvements required a "deal breaker," stated the Operations Hub director. By utilising a TSEF perspective, the company recognised that an end-to-end process change would not only deliver significant benefits but would also widen the influence of its lean ethos (Bamford et al., 2015). Using TSEF to envision what a process should be permitted the case study firm to concentrate upon increasing value and eliminating waste. The resulting company-wide improvement plan (i.e., focusing the factories) built upon previous successes.

Using Simulation to Aid Vision in Managers. The case study's use of DES and animations demonstrated to the organisation the potential of looking at supply chain level improvements. Realising the potential of TSEF required visualising the flow of parcel distribution. For services, developing a map that engages, is dynamic, and represents the flow of value through an organisation is a significant challenge (Bicheno, 2008). Simulations and animations provided such a mechanism for the case study firm. Data analytics provided the platform for TSEF to demonstrate its power to shift the focus of change from a narrow activity focus to a wider enterprise. Through developing simulations to demonstrate the benefits of an even flow of parcels between the process stages, the project team gained buy-in to implement the changes to the process within the operations hub and its linked distribution centres.

"Seeing what would happen to my job once the changes occurred made it easier to support it, though they still have to sort out the number of failures at the Operations Hub for it to work," stated one operator. The visualisations developed through modelling aided the project team in explaining the potential benefits to the organisation. Developing a mechanism which provides employees with the confidence to try new ideas in a safe environment is critical in long-term sustainability for lean improvements (Scherrer-Rathje, Boyle & Deflorin, 2009). Experiments with the physical system would have affected the daily operations, hence, it was decided to use simulations, this is supported by Kelton, Sadowski & Swets (2010, p3). They explain that simulations are a particular useful approach for modelling complex systems. Borschev (2013, p26-36), support this view, and identify simulation as a needed requirement for companies in their decision making process. Discrete even simulation lends itself naturally to be a TSEF tool, since it is based of entities flowing through the system, characterising and defining variations caused in various process stages.

Understanding where Variation Comes From. The research identified that the variability that affects flow can be generated either externally or internally. Customer-derived variability is an important activity in service-based organisations which can be addressed by smoothing the demand entering the process (Akkermans and Voss, 2013). This option, however, was not available to the case study firm. On the other hand, reducing internally generated variance was possible. Our findings illustrate that the major gain for the business was achieved through evenness of flow. Removing the in-built stoppages to smooth flow inherent in the design of the process delivered the improvements sought. Smooth flow, not efficiency of machinery or labour, was the key to unlocking the improvements and subsequent cost savings for the organisation. "We always focus on improving the process as it is. Changing the design of the process is not something that we had considered," remarked the quality manager, reinforcing Skinner's point that changes in process design are "powerful engines" for improvement.

Limitations. Our findings are derived from a single in-depth case study on the application of TSEF in a mass service environment with synchronised activities. This limits the generalizability of the findings, but has allowed the researchers to develop insights that can be examined in the wider contexts of services. It is worth noting, however, that the approach has allowed the organisation to develop a roll-out plan for other sites, highlighting its transferability.

Schmenner *et al* (2009:339) state that the purpose of theories is to "make predictions" of how phenomena work and that the theory can be "disproved by findings that run counter to their predictions or explanations". Our findings have supported the "prediction" of TSEF. However, our research was based on a single case study of a high-volume business that had started to address some of the issues that affect the flow between the two sites. Further research is required to test TSEF in service environments that have different process variety and volume characteristics. Research is needed to examine the deployment of TSEF in environments where the customer is co-creating the service which challenges the standardisation of processes, increases variability and drives serial activities. As TSEF argues that "productivity rises with the speed of flow of materials through a process, and reduces with increases in the variability associated with the flow" (Schmenner and Swink, 1998, p. 102) examining the application of the theory in an agile environment would be a further test of its explanatory power.

Conclusion

Two key questions were posed in conducting this research: (a) Can TSEF break through where lean principles become stymied, and (b) Does DES support the TSEF as a business level improvement tool? The historical improvement approach utilised by the case study company had stagnated at a low level of lean maturity (Hines *et al*; 2004). Lean principles delivered isolated efficiency-based improvements and sub-optimisation across the company-wide processes (Holweg and Pil, 2001). The study demonstrated that DES lends itself naturally as a tool for the TSEF. This allowed the case study firm to enhance its vision for the process, develop focused factories, and substantially reduce costs. Our research has found that TSEF in combination with DES offers service organisations a practical option to improve performance.

Our findings from the case study have allowed us to elaborate on TSEF and how it can stimulate more strategic solutions for productivity (e.g., focused factories). Our research has highlighted several mechanisms that are important for the implementation of TSEF, moving the concept from the academic design board to the practitioner's toolbox. Both strategic and operational elements were found to be important if the potential of swift, even flow is to be realised. The design of the company-wide processes that deliver value and the missions given to different operations may in itself lead to variation that should be managed. Removing or reducing self-induced variation requires a strategic review of the structure of the system (e.g., the character of the focused factories established) that is in addition to the acknowledged variations of the process itself.

References

Akkermans, H. & Voss, C. (2013). The service bullwhip effect, *International Journal of Operations and Production Management*, 33(6) , 765-788

Aitken, J. & Harrison, A. (2013). Supply governance structures for reverse logistics, *International Journal of Operations and Production Management*, 33 (6), 745-764

Balle, M. (2005), Lean attitude, *IEE Manufacturing Engineer*, April/May, 14-19

Bamford, D., Foresster, P., Dehe, B. & Lesse, R. (2015), "Partial and iterative lean implementation: two case studies", *International Journal of Operations and Production Management*, 35 (5), 702-727

Barratt, M., Choi, T. & Li, M. (2011), Qualitative case studies in operations management: Trends, research outcomes, and future research implications, *Journal of Operations Management*, 29 (4), 329-342

Bicheno,J. (2008), The Lean Toolbox: The Essential Guide to Lean Transformation (4th ed.). Buckinghamshire, UK, PICSIE books.

Bitektine A. (2008), Prospective case study design qualitative method for deductive theory testing, *Organizational Research Methods*, 11 (1), 160-180

Boer, H., Holweg, M., Kilduff, M., Pagell, M., Schmenner, R. & Voss, C., (2015), Making a meaningful contribution to theory, *International Journal of Operations and Production Management*, 35 (9), 1231 – 1252

Borshchev, A., (2013), The big book of simulation modeling: multimethod modeling with AnyLogic 6. North America

Checkland, P. (1981), Systems Thinking, Systems Practice, Wiley, New York

Deveraji, S., Ow, T. & Kohli, R. (2013), Examining the impact of information technology and patient flow: A theory of swift even flow (TSEF) perspective *Journal of Operations Management*, 31, 181-192

Ellram, L., Tate, W. & Billington, C. (2004), Understanding and managing services supply chains, *The Journal of Supply Chain Management*, 40 (4), 17-32

Eisenhardt, K. (1989), Building theories from case study research. *Academy of Management Review*, 14(4), 532-550.

Fredendall, L., Craig, J. , Fowler, P. & Damali, U. (2009), Barriers to Swift, Even Flow in the Internal Supply Chain of Preoperative Surgical Services Department: A Case Study. *Decision Science*, 40 (2), 327-348

Frohlich, M. & Westbrook, R. (2001), Arcs of integration: an international study of supply chain strategies, *Journal of Operations Management*, 19 (2), 185-200

Gurumurthy, A. and Kodali, R. (2011), " Design of lean manufacturing systems using value stream mapping with simulation", *International Journal of Technology Management*, Vol.22, No. 4, pp 444-473

Hall, Robert W., (1987), *Attaining Manufacturing Excellence*, Homewood, Ill.: Dow Jones‑Irwin, NY

Hall, Robert W.,(1983), *Zero Inventories*, Homewood, Ill.: Dow Jones‑Irwin,NY

Heizer, J. and Render, B. (2011), *Operations Management* (10 ed.). Upper Saddle River, N.J: Prentice Hall

Hines, P., Holweg, M. and Rich, N. (2004), "Learning to evolve: a review of contemporary lean thinking". *International Journal of Operations* and *Production Management*, Vol.24, No. 10, pp 994-1011

Howleg, M, (2007), "The genealogy of lean production", *Journal of Operations Management*, Vol. 25, No. 2, pp 420-437

Holweg, M. and Pil, F. (2001), "Successful build-to-order strategies start with the customer", *Sloan Management Review*, Vol. 43, No. 1, pp. 74-83.

Kelton, W.D., Sadowski, R.P. and Swets N.B. (2009), *Simulation with Arena* (5 ed.), McGraw-Hill, Inc., New York, NY, USA

Ketokivi, M., and Choi, T. (2014). "Renaissance of case research as a scientific method". *Journal of Operations Management*, Vol. 32, No. 5, pp 232-240.

Krafick, J. (1988), "The triumph of the lean production system", *Sloan Management Review*, Vol.30, No. 1, pp 41-52

Liker, Jeffery K. (2004), *The Toyota Way: Fourteen Management Principles from the World's Greatest Manufacturer*. New York: McGraw-Hill.NY

Marvel, J.H. and Stanbridge, C.R. (2009), "A simulation-enhanced lean design process", *Journal of Industrial Engineering and Management*, Vol. 2, No. 1, pp 90-113

Meredith, J. (1998), "Building operations management theory through case and filed research", *Journal of Operations Management*, Vol. 16, No. 4, pp 439-452

Miles, M. and Huberman A. (1994), *An expanded sourcebook qualitative data analysis (2nd ed.).* Thousand Oaks, California: Sage Publishing

MIT (2000), *Transitioning to a Lean Enterprise: A guide for leaders, 1/2/3*, available at: http://lean.mit.edu/Products/TTL/TTL-vo11.pdf

Narasimhan, R. (2014), "Theory Development in Operations Management: Extending the Frontiers of a Mature Discipline via Qualitative Research", *Decision Sciences*, Vol. 45, pp 209-227

Pagell, M. (2004), "Understanding factors that enable and inhibit the integration of operations, purchasing, and logistics", *Journal of Operations Management*, Vol. 22, No. 50, pp 459-487

Papadopoulou, T. and Ozbayrak, M. (2005), "Leanness: experience from the journey to date", *International Journal of Technology Management*, Vol.16, No. 7, pp 784-807

Rahbek, E., Pedersen, G. and Huniche, M. (2011), "Determinants of lean success and failure in the Danish public sector: A negotiated order", *International Journal of Public Sector Management*, Vol. 24, No. 5, pp 403-420

Radnor, Z., Walley, P.,Stephens, A. and Bucci, G., (2006), *"Evaluation of the lean approach to business management and its use in the public sector*", Government Social Research, Edinburgh

Rich, N. and Bateman, N. (2003), "Companies' perceptions of inhibitors and enablers for process improvement activities", *International Journal of Operations and Production Management*, Vol. 23, No. 2, pp 185-199

Scherrer-Rathje, M., Boyle, T. and Deflorin, P. (2009) "Lean, take two! Reflections from the second attempt at lean implementation" *Business Horizons*, Vol. 52, No. 1, pp 79-88

Schmenner, R.W. (1991), "International Factory Productivity Gains", *Journal of Operations Management*, Vol. 10, No. 2, pp 229-254

Schmenner, R. W., & Swink, M. L. (1998). On theory in operations management. *Journal of Operations Management*, Vol. 17, No. 1, pp 97–113.

Schmenner, R.W. (2001), "Looking Ahead by Looking Back: Swift, Even Flow in the History of

Manufacturing”, *Production and Operations Management*, Vol. 10, No. 1, pp.87-96.

Schmenner, R.W. (2004), “Service Businesses and Productivity”, *Decision Sciences*, Vol. 35, No. 3, pp 333-347

Schmenner, R. W., Van Wassenhove, L., Ketokivi, M., Heyl, J., & Lusch, R. F. (2009). Too much theory, not enough understanding. Journal of Operations Management, 27(5), 339-343.

Schmenner. R.W. (2012), *Getting and Staying Productive: Applying Swift, Even Flow to Practice*. Cambridge, Cambridge University Press.

Schmenner, R.W. (2015), “The Pursuit of Productivity”, *Production and Operations Management*, Vol.24, No. 2, pp 341-50

Schilling, J and Kluge, A. (2009), “Barriers to organisational learning: An integration of theory and research”. *International Journal of Management Reviews*, Vol. 11, No.3, pp 337-360

Schonberger, R.J. (1982), *Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity*. London, The Free Press, Macmillan Publishing.

Shah, R., Goldstein, S., Unger, B and Henry, T., (2008). “Explaining anomalous high performance in a health care supply chain”. *Decision Sciences*, Vol. 39, No. 4, pp.759-789.

Simons, D. and Taylor, D. (2007),” Lean thinking in the UK red meat industry: A systems and contingency approach”, *International Journal of Production Economics*, Vol. 106, pp 70-81

Skinner, W. (1974), “The Focused Factory”, *Harvard Business Review*, Vol.53, No.3, pp 113-121

Skinner, W. (1986), “The productivity paradox”, *Harvard Business Review*, Vol. 64, No. 4, pp 55-59 Simons, D. and Taylor, D. (2007), Lean thinking in the UK red meat industry: A systems and contingency approach, *International Journal of Production Economics*, Vol.106, No. 1, pp 70-81

Smart, P., Tranfield, D, Deasley, P., Levene. R., Rowe, A. and Corley, J. (2003), “Integrating “lean and “high reliability”, thinking”, Proceedings of Institution of Mechanical Engineers, Part B, *Journal of Engineering Manufacture*, Vol. 217 , pp 733- 739

Staats, B.R., Brunner, D.J. and Upton, D.M. (2011), “Lean principles, learning, and knowledge work: Evidence from a software service provider”, *Journal of Operations Management*, Vol.29, No. 5, pp 376-390

Thompson, G. M. (1992), “Improving the Utilization of Front-Line Service Delivery System Personnel”, *Decision Sciences*, Vol. 23, pp 1072-1098

Voss, C., Tsikriktsis, N., Frohlich, M. (2002), “Case research in operations management”, *International Journal of Operations and Production Management*, Vol. 22, No. 2.pp 195-219

Womack, J and Jones, D, (1996), *Lean thinking*, Simon and Schuster, NY

Yin, R. (2003). *Case Study Research: Design and Methods (3rd ed.).* London, Sage Publishers.