The seven value stream mapping tools

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Introduction

Work carried out in the first Supply Chain Development Programme (SCDP I), together with early work in the second programme (SCDP II), has shown that in order fully to understand the different value streams[1] in which the sponsors operate, it is necessary to map these intercompany and intracompany value-adding processes. These value-adding processes make the final product or service more valuable to the end consumer than otherwise it would have been. The difference between the traditional supply or value chain and the *value stream* is that the former includes the complete activities of all the companies involved, whereas the latter refers only to the specific parts of the firms that actually add value to the specific product or service under consideration. As such the value stream is a far more focused and contingent view of the value-adding process.

At present, however, there is an ill-defined and ill-categorized toolkit with which to understand the value stream, although several workers (e.g. [2-5]) have developed individual tools. In general these authors have viewed their creations as *the* answer, rather than as a part of the jigsaw. Moreover, these tools derive from functional ghettos and so, on their own, do not fit well with the more cross-functional toolbox required by today's best companies. It is the purpose of this paper to construct a typology or total jigsaw to allow for an effective application of sub-sets of the complete suite of tools. The tools themselves can then effectively be applied, singularly or in combination, contingently to the requirements of the individual value stream.

Waste removal inside companies

The rationale underlying the collection and use of this suite of tools is to help researchers or practitioners to identify waste in individual value streams and, hence, find an appropriate route to removal, or at least reduction, of this waste. The use of such waste removal to drive competitive advantage inside organizations was pioneered by Toyota's chief engineer, Taiichi Ohno, and

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sensei Shigeo Shingo[6,7] and is oriented fundamentally to productivity rather than to quality. The reason for this is that improved productivity leads to leaner operations which help to expose further waste and quality problems in the system. Thus the systematic attack on waste is also a systematic assault on the factors underlying poor quality and fundamental management problems[8].

In an internal manufacturing context, there are three types of operation that are undertaken according to Monden[9]. These can be categorized into:

(1) non-value adding (NVA);

(2) necessary but non-value adding (NNVA); and

(3) value-adding (VA).

The first of these is pure waste and involves unnecessary actions which should be eliminated completely. Examples would include waiting time, stacking intermediate products and double handling.

Necessary but non-value adding operations may be wasteful but are necessary under the current operating procedures. Examples would include: walking long distances to pick up parts; unpacking deliveries; and transferring a tool from one hand to another. In order to eliminate these types of operation it would be necessary to make major changes to the operating system such as creating a new layout or arranging for suppliers to deliver unpacked goods. Such change may not be possible immediately.

Value-adding operations involve the conversion or processing of raw materials or semi-finished products through the use of manual labour. This would involve activities such as: sub-assembly of parts, forging raw materials and painting body work.

The seven wastes

There are seven commonly accepted wastes in the Toyota production system (TPS):

(1) overproduction;

(2) waiting;

(3) transport;

(4) inappropriate processing;

(5) unnecessary inventory;

(6) unnecessary motion;

(7) defects.

Overproduction is regarded as the most serious waste as it discourages a smooth flow of goods or services and is likely to inhibit quality and productivity. Such overproduction also tends to lead to excessive lead and storage times. As a result defects may not be detected early, products may deteriorate and artificial pressures on work rate may be generated. In addition, overproduction leads to excessive work-in-progress stocks which result in the physical dislocation of operations with consequent poorer communication. This state of affairs is often encouraged by bonus systems that encourage the push of unwanted goods. The pull or *kanban* system was employed by Toyota as a way of overcoming this problem.

When time is being used ineffectively, then the waste of *waiting* occurs. In a factory setting, this waste occurs whenever goods are not moving or being worked on. This waste affects both goods and workers, each spending time waiting. The ideal state should be no waiting time with a consequent faster flow of goods. Waiting time for workers may be used for training, maintenance or *kaizen* activities and should not result in overproduction.

The third waste, *transport*, involves goods being moved about. Taken to an extreme, any movement in the factory could be viewed as waste and so transport minimization rather than total removal is usually sought. In addition, double handling and excessive movements are likely to cause damage and deterioration with the distance of communication between processes proportional to the time it takes to feed back reports of poor quality and to take corrective action.

Inappropriate processing occurs in situations where overly complex solutions are found to simple procedures such as using a large inflexible machine instead of several small flexible ones. The over-complexity generally discourages ownership and encourages the employees to overproduce to recover the large investment in the complex machines. Such an approach encourages poor layout, leading to excessive transport and poor communication. The ideal, therefore, is to have the smallest possible machine, capable of producing the required quality, located next to preceding and subsequent operations. Inappropriate processing occurs also when machines are used without sufficient safeguards, such as *poke-yoke* or *jidoka* devices, so that poor quality goods are able to be made.

Unnecessary inventory tends to increase lead time, preventing rapid identification of problems and increasing space, thereby discouraging communication. Thus, problems are hidden by inventory. To correct these problems, they first have to be found. This can be achieved only by reducing inventory. In addition, unnecessary inventories create significant storage costs and, hence, lower the competitiveness of the organization or value stream wherein they exist.

Unnecessary movements involve the ergonomics of production where operators have to stretch, bend and pick up when these actions could be avoided. Such waste is tiring for the employees and is likely to lead to poor productivity and, often, to quality problems.

The bottom-line waste is that of *defects* as these are direct costs. The Toyota philosophy is that defects should be regarded as opportunities to improve rather than something to be traded off against what is ultimately poor management. Thus defects are seized on for immediate *kaizen* activity.

In systems such as the Toyota production system, it is the continuous and iterative analysis of system improvements using the seven wastes that results in a *kaizen*-style system. As such, the majority of improvements are of a small but incremental kind, as opposed to a radical or breakthrough type.

Waste removal inside value streams

As the focus of the value stream includes the complete value adding (and non-value adding) process, from conception of requirement back through to raw material source and back again to the consumer's receipt of product, there is a clear need to extend this internal waste removal to the complete supply chain. However, there are difficulties in doing this. These include lack of visibility along the value stream and lack of the tools appropriate to creating this visibility. This paper aims to help researchers and practitioners remedy such deficiencies. The waste terminology described above has been drawn from a manufacturing environment, specifically from the automotive industry, and from a Japanese perspective. As a result some translation of the general terminology will be required to adapt it to a particular part of the value stream and to particular industries in non-Japanese settings. Consequently, a contingency approach is required to some extent.

Such an approach has been the subject of considerable previous work at the Lean Enterprise Research Centre. This would include the application by Hines[10] of the *kyoryoku kai* (supplier association) to a range of UK-based industry sectors and the introduction by Jones[11] of the Toyota production system philosophy to a warehouse environment. Jones has shown that the seven wastes required rewording to fit an after-market distribution setting. He therefore retitled the seven wastes as:

(1) faster-than-necessary pace;

(2) waiting;

(3) conveyance;

(4) processing;

(5) excess stock;

(6) unnecessary motion; and

(7) correction of mistakes.

The seven value stream mapping tools

The typology of the seven new tools is presented in terms of the seven wastes already described. In addition the delineating of the overall combined value stream structure will be useful and will also be combined as shown in the left-hand column in Table I. Thus, in order to make improvements in the supply chain it is suggested here that at least an outline understanding of the particular wastes to be reduced must be gained before any mapping activity takes place.

At this point it should be stressed that several of the seven mapping tools were already well-known before the writing of this paper. At least two can be regarded as new, and others will be unfamiliar to a wide range of researchers

Wastes/structure	Mapping tool Process activity mapping	Supply chain response matrix	Production variety funnel	Quality filter mapping	Demand amplification mapping	Decision point analysis	Physical structure (a) volume (b) value
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H

Notes: H =High correlation and usefulness
M = Medium correlation and usefulness
L = Low correlation and usefulness

Table I.
The seven stream mapping tools

and practitioners. Until now, however, there has been no decision support mechanism to help choose the most appropriate tool or tools to use.

The tools themselves are drawn from a variety of origins as show in Table II. These origins include engineering (tools 1 and 5), action research/logistics (tools 2 and 6) operations management (tool 3), and two that are new (tools 4 and 7). As can be seen, they are generally from specific functional ghettos and so the full range of tools will not be familiar to many researchers, although specific tools may be well-known to individual readers. Each of these is reviewed in turn before a discussion is undertaken of how they can be selected for use.

Mapping tool	Origin of mapping tool
(1) Process activity mapping	Industrial engineering
(2) Supply chain response matrix	Time compression/logistics
(3) Production variety funnel	Operations management
(4) Quality filter mapping	New tool
(5) Demand amplification mapping	Systems dynamics
(6) Decision point analysis	Efficient consumer response/logistics
(7) Physical structure mapping	New tool

Table II.
Origins of the seven value stream mapping tools

The tools

Process activity mapping

As noted above, process activity mapping has its origins in industrial engineering. Industrial engineering comprises a group of techniques that can be used to eliminate from the workplace waste, inconsistencies and irrationalities, and provide high-quality goods and services easily, quickly and inexpensively[12]. The technique is known by a number of names in this context, although process analysis is the most common[13].

There are five stages to this general approach:

(1) the study of the flow of processes;

(2) the identification of waste;

(3) a consideration of whether the process can be rearranged in a more efficient sequence;

(4) a consideration of a better flow pattern, involving different flow layout or transport routeing; and

(5) a consideration of whether everything that is being done at each stage is really necessary and what would happen if superfluous tasks were removed.

Process activity mapping involves the following simple steps: first, a preliminary analysis of the process is undertaken, followed by the detailed recording of all the items required in each process. The result of this is a map of the process under consideration (see Figure 1). As can be seen from this process industry example, each step (one-23) has been categorized in terms of a variety of activity types (operation, transport, inspection and storage). The machine or area used for each of these activities is recorded, together with the distance moved, time taken and number of people involved. A simple flow chart of the types of activity being undertaken at any one time can then be made. These are depicted by the darker shade boxes in Figure 1.

Next the total distance moved, time taken and people involved can be calculated and recorded. The completed diagram (Figure 1) can then be used as the basis for further analysis and subsequent improvement. Often this is achieved through the use of techniques such as the 5W1H (asking: *Why* does an activity occur? *Who* does it? On *which* machine? *Where*? *When*? and *How*?). The basis of this approach is therefore to try to eliminate activities that are unnecessary, simplify others, combine yet others and seek sequence changes that will reduce waste. Various contingent improvement approaches can be mapped similarly before the best approach is selected for implementation.

Supply chain response matrix

The origin of the second tool is the time compression and logistics movement and goes under a variety of names. It was used by New[2] and by Forza *et al.*[3] in a textile supply chain setting. In a more wide-ranging work, Beesley[4] applied what he termed “time-based process mapping” to a range of industrial

#	STEP	FLOW	MACHINE	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
1	RAW MATERIAL	S	RESERVOIR				O	T	I	S	D	RESERVOIR/ ADDITIVES
2	KITTING	O	WAREHOUSE	10	5	1	O	T	I	S	D	
3	DELIVERY TO LIFT	T		120		1	O	T	I	S	D	
4	OFFLOAD FROM LIFT	T			0.5	1/2	O	T	I	S	D	
5	WAIT FOR MIX	D	MIX AREA		20		O	T	I	S	D	
6	PUT IN CRADLE	T		20	2	1/2	O	T	I	S	D	
7	PIERCE/POUR	O	MIX AREA 12		0.5	1	O	T	I	S	D	
8	MIX (BLOWERS)	O			20	1/2	O	T	I	S	D	BASE MATERIAL, BLOW & ADDITIVES
9	TEST #1	I			30	1+1	O	T	I	S	D	SAMPLE/TEST
10	PUMP TO STORAGE TANK	T	STORE TANK	100		1	O	T	I	S	D	DEDICATED RESERVOIR
11	MIX IN STORAGE TANK	O	STORE TANK		10	1	O	T	I	S	D	
12	I.R. REST	I			10	1+1	O	T	I	S	D	STAMP & APPROVE
13	AWAIT FILLING	D			15		O	T	I	S	D	LONGER IF SCREEN LATE
14	TO FILLER HEAD	T		20	0.1	1	O	T	I	S	D	
15	FILL/TOP/TIGHTEN	O	FILLER HEAD		1	1+1	O	T	I	S	D	1 UNIT
16	STACK	T	PALLET	3	0.1	1	O	T	I	S	D	1 UNIT
17	DELAY TO FILL 1 PALLET	D			30		O	T	I	S	D	
18	STRAP PALLET	O			2	1	O	T	I	S	D	
19	TRANSFER TO STORE	T		80	2	1	O	T	I	S	D	
20	AWAIT TRUCK	D	STORE		540		O	T	I	S	D	BATCH 360/ QUEUE 180
21	PICK/MOVE BY FORK LIFT	T		90	3	1	O	T	I	S	D	FORK LIFT
22	WAIT TO FILL FULL LOAD	D	LORRY		30	1+1	O	T	I	S	D	1 OPERATOR, 1 HAULIER
23	AWAIT SHIPMENT	D	LORRY		60	1	O	T	I	S	D	1 HAULIER
	TOTAL		23 STEPS	443	781.2	25	6	8	2	1	6	
	OPERATORS				38.5	8						
	% VALUE ADDING				4.93%	32%						

Figure 1.
Users and non-users of DFM

sectors including automotive, aerospace and construction. A similar, if slightly refined, approach was adopted by Jessop and Jones[5] in the electronics, food, clothing and automotive industries.

This mapping approach, as shown in Figure 2, seeks to portray in a simple diagram the critical lead-time constraints for a particular process. In this case it is the cumulative lead time in a distribution company, its suppliers and its downstream retailer. In Figure 2 the horizontal measurements show the lead time for the product both internally and externally. The vertical plot shows the average amount of standing inventory (in days) at specific points in the supply chain.

In this example the horizontal axis shows the cumulative lead time to be 42 working days. The vertical axis shows that a further 99 working days of material are held in the system. Thus a total response time in this system of 141 working days can be seen to be typical. Once this is understood, each of the individual lead times and inventory amounts can be targeted for improvement activity, as was shown with the process activity mapping approach.

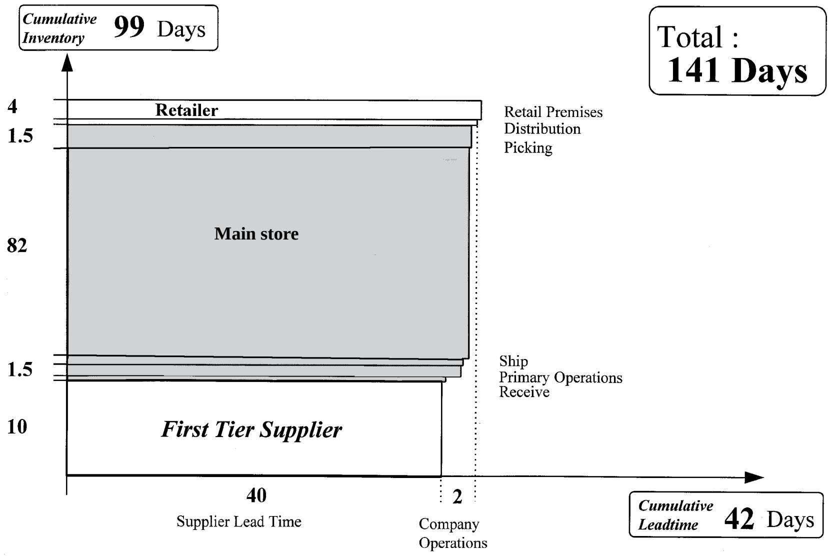


Figure 2.
Supply chain response matrix – a distribution example

Production variety funnel

The production variety funnel is shown in Figure 3. This approach originates in the operations management area[14] and has been applied by New[2] in the textiles industry. A similar method is IVAT analysis which views internal operations in companies as consisting of activities that conform to I, V, A or T shapes[15]:

- "I" plants consist of unidirectional, unvarying production of multiple identical items such as a chemical plant.
- "V" plants consist of a limited number of raw materials processed into a wide variety of finished products in a generally diverging pattern.
- "V" plants are typical in textiles and metal fabrication industries.
- "A" plants, in contrast, have many raw materials and a limited range of finished products with different streams of raw materials using different facilities; such plants are typical in the aerospace industry or in other major assembly industries.
- "T" plants have a wide combination of products from a restricted number of components made into semi-processed parts held ready for a wide range of customer-demanded final versions; this type of site is typical in the electronics and household appliance industries.

Such a delineation using the production variety funnel (Figure 3) allows the mapper to understand how the firm or the supply chain operates and the accompanying complexity that has to be managed. In addition, such a mapping process helps potential research clients to understand the similarities and differences between their industry and another that may have been more widely researched. The approach can be useful in helping to decide where to target

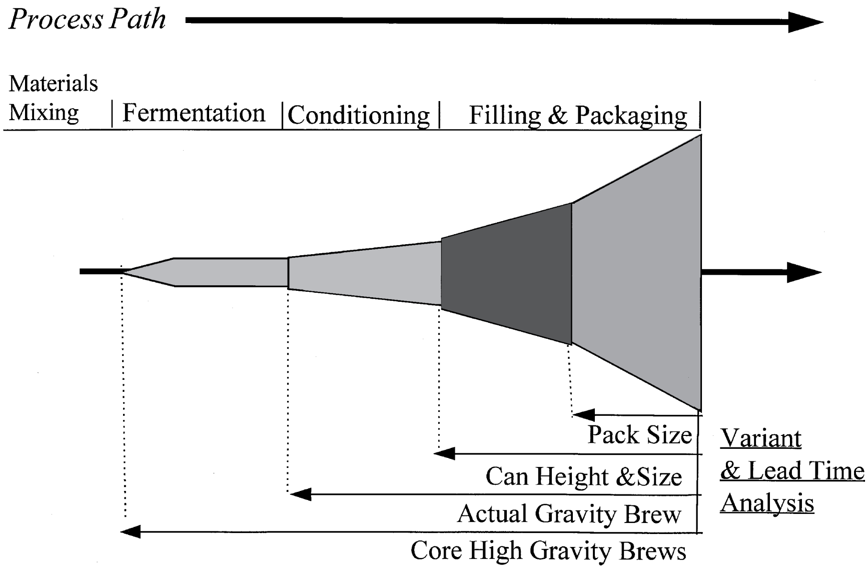


Figure 3.
Production variety funnel – a brewing industry case

inventory reduction and making changes to the processing of products. It is also useful in gaining an overview of the company or supply chain being studied.

Quality filter mapping

The quality filter mapping approach is a new tool designed to identify where quality problems exist in the supply chain. The resulting map itself shows where three different types of quality defect occur in the supply chain (see Figure 4):

(1) The first of these is the *product* defect. Product defects are defined here as defects in goods produced that are not caught by in-line or end-of-line inspections and are therefore passed on to customers.

(2) The second type of quality defect is what may be termed the *service* defect. Service defects are problems given to a customer that are not directly related to the goods themselves, but rather are results of the accompanying level of service. The most important of these service defects are inappropriate delivery (late or early), together with incorrect paper work or documentation. In other words, such defects include any problems that customers experience which are not concerned with production faults.

(3) The third type of defect is *internal scrap*. Internal scrap refers to defects produced in a company that have been caught by in-line or end-of-line inspection. The in-line inspection methods will vary and can consist of traditional product inspection, statistical process control or through poke-yoke devices.

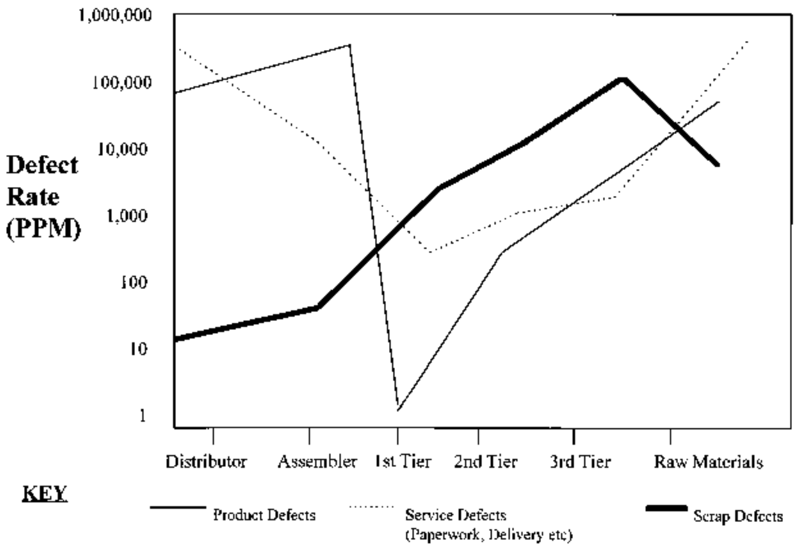


Figure 4. The quality filter mapping approach – an automotive example

Each of these three types of defect are then mapped latitudinally along the supply chain. In the automotive example given (Figure 4), this supply chain is seen to consist of distributor, assembler, first-tier supplier, second-tier supplier, third-tier supplier and raw material source. This approach has clear advantages in identifying where defects are occurring and hence in identifying problems, inefficiencies and wasted effort. This information can then be used for subsequent improvement activity.

Demand amplification mapping

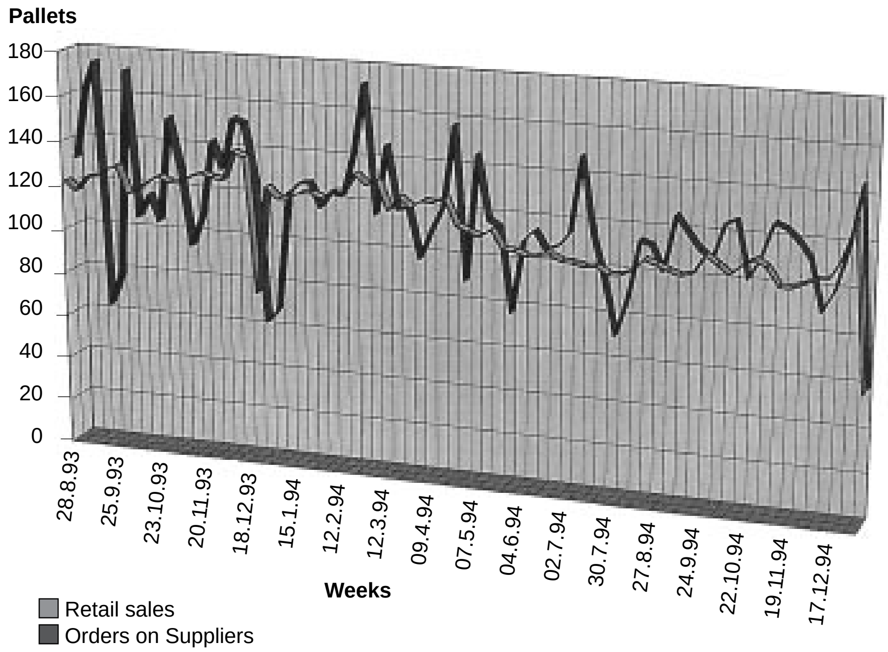
Demand amplification mapping has its roots in the systems dynamics work of Forrester[16] and Burbidge[17]. What is now known as the "Forrester effect" was first described in a *Harvard Business Review* article in 1958 by Forrester[16]. This effect is linked primarily to delays and poor decision making concerning information and material flow. The Burbidge effect is linked to the "law of industrial dynamics" which states:

> if demand is transmitted along a series of inventories using stock control ordering, then the amplification of demand variation will increase with each transfer[17].

As a result, in unmodified supply chains generally excess inventory, production, labour and capacity are found. It is then quite likely that on many day-to-day occasions manufacturers will be unable to satisfy retail demand even though on average they are able to produce more goods than are being sold. In a supply chain setting, manufacturers therefore have sought to hold – in some cases sizeable – stocks to avoid such problems. Forrester[16] likens this to driving an automobile blindfolded with instructions being given by a passenger.

The use of various mapping techniques loosely based on Forrester and Burbidge's pioneering work is now quite common (e.g. [18]) and in at least one case the basic concept has even been developed into a game called *The Beer Game*[19] which looks at the systems-dynamics within a retail brewing situation[19]. The basis of the mapping tool in the supply chain setting is given in Figure 5. In this instance an FMCG food product is being mapped along its distribution through a leading UK supermarket retailer. In this simple example two curves are plotted. The first, in the lighter shading, represents the actual consumer sales as recorded by electronic point-of-sale data. The second, and darker, curve represents the orders placed to the supplier to fulfil this demand. As can be seen, the variability of consumer sales is far lower than it is for supplier orders. It is also possible subsequently to map this product further upstream. An example may be the manufacturing plant of the cleaning products company or even the demand they place on their raw material suppliers.

This simple analytic tool can be used to show how demand changes along the supply chain in varying time buckets. This information then can be used as the basis for decision making and further analysis to try to redesign the value stream configuration, manage the fluctuations, reduce the fluctuation or to set



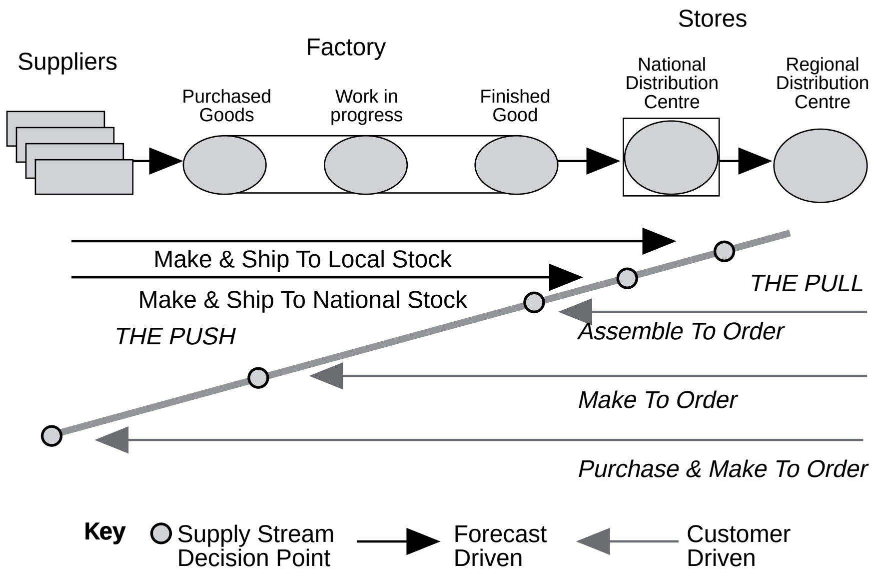
Source: [11]

Figure 5.
Demand amplification mapping – an FMCG food product sample

up dual-mode solutions where regular demand can be managed in one way and exceptional or promotional demand can be managed in a separate way[20].

Decision point analysis

Decision point analysis is of particular use for "T" plants or for supply chains that exhibit similar features, although it may be used in other industries. The decision point is the point in the supply chain where actual demand pull gives way to forecast-driven push. In other words, it is the point at which products stop being made according to actual demand and instead are made against forecasts alone[21]. Thus, with reference to Figure 6 – an example from the FMCG industry – the decision point can be at any point from regional distribution centres to national distribution centres through to any point inside the manufacturer or indeed, at any tier in the supply chain[22].



Source: [22]

Figure 6. Decision point analysis – an FMCG example

Gaining an understanding of where this point lies is useful for two reasons:

(1) In terms of the present, with this knowledge it is possible to assess the processes that operate both downstream and upstream from this point. The purpose of this is to ensure that they are aligned with the relevant pull or push philosophy.

(2) From the long-term perspective, it is possible to design various "what if" scenarios to view the operation of the value stream if the decision point is moved. This may allow for a better design of the value stream itself.

Physical structure

Physical structure mapping is a new tool which has been found to be useful in understanding what a particular supply chain looks like at an overview or industry level. This knowledge is helpful in appreciating what the industry looks like, understanding how it operates and, in particular, in directing attention to areas that may not be receiving sufficient developmental attention.

The tool is illustrated in Figure 7 and can be seen to be split into two parts, namely: volume structure and cost structure. The first diagram (Figure 7(a)) shows the structure of the industry according to the various tiers that exist in both the supplier area and the distribution area, with the assembler located at the middle point. In this simple example, there are three supplier tiers as well as three mirrored distribution tiers. In addition, the supplier area is seen to include raw material sources and other support suppliers (such as tooling, capital equipment and consumable firms). These two sets of firms are not given a tier level as they can be seen to interact with the assembler as well as with the other supplier tiers.

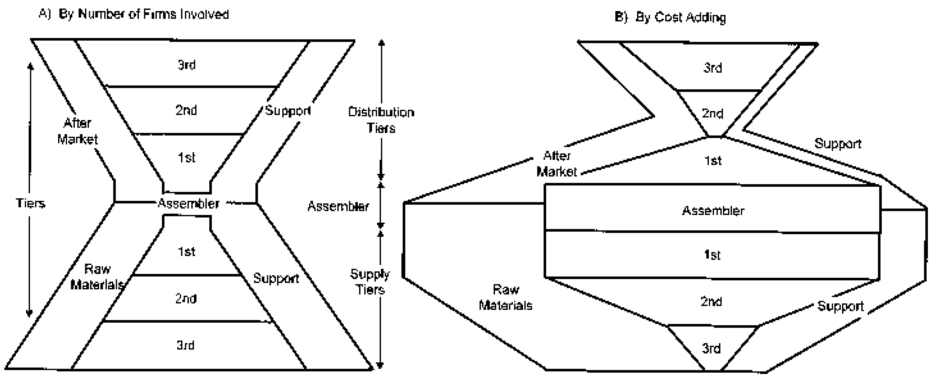


Figure 7.
Physical structure mapping – an automotive industry example

The distribution area in Figure 7 includes three tiers as well as a section representing the after-market (in this case for spare parts), as well as various other support organizations providing consumables and service items. This complete industry map therefore captures all the firms involved, with the area of each part of the diagram proportional to the number of firms in each set.

The second diagram maps the industry in a similar way with the same sets of organizations. However, instead of linking the area of the diagram to the number of firms involved, it is directly linked to the value-adding process (or, more strictly to the cost-adding process). As can be noted in this automotive case, the major cost adding occurs in the raw material firms, the first-tier suppliers and the assembler, respectively. The distribution area is not seen to be a major cost-adding area.

The basis for use of this second figure, however, is that it is then possible to analyse the value adding required in the final product as it is sold to the consumer. Thus value analysis or function analysis tools employed by industrial engineers can be focused at the complete industry or supply chain structure[23,24]. Such an approach may result in a redesign of how the industry itself functions. Thus, in a way similar to the application of the process activity mapping tool discussed above, attempts can be made to try to eliminate activities that are unnecessary, to simplify others, combine yet others and to seek sequence changes that will reduce waste.

Using the toolkit

The use of this toolkit at this stage should not be confined to any particular theoretical approach to ultimate implementation. Thus the options can be left open at this stage over whether to adopt a *kaizen* or business process re-engineering approach once the tools have been used[25,26]. It is the authors' belief that the framework does not constrain this choice process.

Value stream mapping tools

The specific focusing of which tools to use in what circumstances is done using a simplified version of the value stream analysis tool (VALSAT)[27]. The first part of this process is to identify the specific value stream to be reviewed. Second, through a series of preliminary interviews with managers in the value stream, it is necessary to identify the various wastes that exist in the value stream that managers believe can and should be removed (reference should be made to the earlier discussion of the seven wastes). In addition, it is important to gain the views of these managers on the importance of understanding the complete industry structure, irrespective of which wastes are to be removed.

This selection of tools is achieved by giving the interviewees a written overview of each of the wastes as well as an explanation of what is meant by the industry structure. At this stage, if necessary, descriptions of the seven wastes may be reworded in terms more appropriate to the industry under consideration. For instance, in the health-care industry the concept of *overproduction* may not have great value. However, to call this potential waste "doing things too early" instead may be more useful in getting the interviewees to relate the concept to their own situations.

Once this has been done, the reworded seven wastes and the account of the overall structure are recorded as row eight in the VALSAT in Table I diagram, or as eight rows in area A of Figure 8. Comparison of Table I and Figure 8 will show that the former is a simplification of the latter but with sections A, B and C already completed. Thus using this VALSAT method, the different approaches to identifying how these eight variables can be mapped has already been completed by the addition of the seven value stream mapping tools (B). In addition, area C of Figure 8 has already been completed as the correlation between tools and wastes was completed within the main body of Table I.

At this point it is informative to ask the firm or firms involved to identify for each of the eight wastes/structure (D) the benchmark company in their sector. In other words, by opening these discussions at this stage it forces the firm to

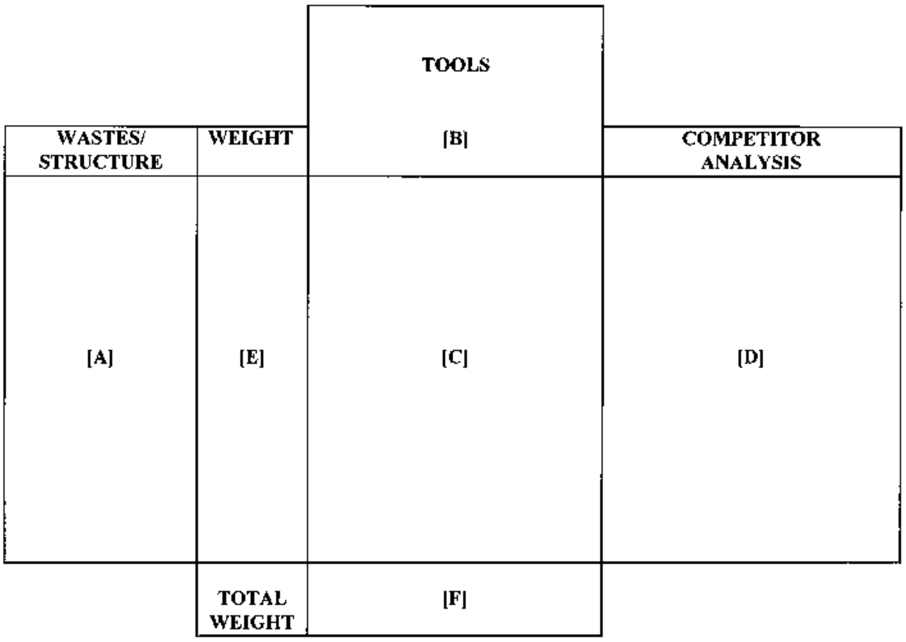


Figure 8.
Using the VALSAT approach to select effective value stream mapping tools

think about which of their competitors is best at reducing particular wastes and managing their complete supply/distribution chain. This knowledge may then lead on to more formal benchmarking with these companies, if this is felt to be appropriate, or at least a good focus for subsequent mapping activities.

The next stage (E), therefore, is to ascertain the individual importance weighting of the seven wastes and the overall industry structure. This is achieved most effectively by allocating a total of 40 points for the eight factors and asking the interviewee to apportion these on the basis of an importance rating between the factors, with the proviso that no one factor can attract more than ten points. If there is more than one interviewee, then the different scores may be aggregated and rebased to total 40 points.

The last arithmetical stage of this approach is to create total weights for each tool. In effect, what is being done here is to give a rating to each tool in terms of how useful it is in identifying the various wastes designated as of most importance by the organization or organizations. This is achieved by giving each of the different correlations given in Table I a score. Thus, high correlations are equivalent to nine points; medium three points; and low, to a single point. Then, for each correlation, a total importance score is calculated. This is achieved by multiplying the weighting of each waste/structure by the correlations. Thus, referring to the correlations in Table I, if the weighting for overproduction is six points the usefulness of the tools in addressing overproduction will be:

- six for process activity mapping (6×1);
- 18 for supply chain response matrix (6×3);
- zero for production variety funnel (6×0);
- six for quality filter mapping (6×1);
- 18 for demand amplification mapping (6×3);
- 18 for decision point analysis (6×3); and
- zero for physical structure mapping (6×0).

This type of calculation is then applied to each of the other rows so that scores are recorded for each individual correlation. Once this is complete the total scores for each column are then summed and recorded in the total weight section, or "F" in Figure 8. The columns which have the highest scores are those that contain the most appropriate tools. As a rule of thumb it is useful to choose more than one tool. Indeed, as a final check, the more important two or three wastes/structure should have been addressed by tools with which they are highly correlated or failing this by at least two tools with which they have a medium correlation. This will ensure that each waste/structure is covered adequately in the mapping process.

This section therefore will have assisted the reader to identify which tool or tools to use. However, once the tools have been run it may be that some unexpectedly high wastes have become apparent. For instance, the demand amplification mapping tool may have been employed to identify unnecessary inventory and waiting. However, as the tool also has a medium correlation with overproduction, it will be useful in identifying such waste if it exists but was not recognized at first by the managers involved. This backflushing may therefore identify some unanticipated but potential improvement areas and, hence, lead to some breakthroughs.

After this mapping process is complete, the researcher will be able to use each individual tool with its associated benefits to undertake more detailed analysis of the value stream with a view to its improvement. As stated above, it is not the purpose of this paper to convert other researchers to a *kaizen* or business process re-engineering approach in this subsequent work. However, the various mapping tools described will help with whichever approach is chosen. In general, the removal of non-value adding waste is best done using a *kaizen* approach, whereas the removal of necessary but non-value adding waste requires a more revolutionary strategy wherein the application of business process re-engineering may be more appropriate.

Case example

For the reader to gain a better understanding of the approach, a brief case example will be reviewed. The company involved is a highly profitable leading industrial distributor with over 60,000 products and an enviable record for customer service.

After undertaking preliminary discussions it was decided to focus on the upstream value stream to the point at which goods are available for distribution by the firm. Nine products were chosen based on a Pareto analysis from one particular value stream, namely: the lighting product range. Within this range, interviews with key cross-functional staff showed that unnecessary inventory, defects, inappropriate processing and transport were the most serious wastes in the system. In order to understand this in more detail, and using the mapping correlation matrix (Table I), it was decided to adopt five of the tools:

(1) process activity mapping;

(2) supply chain response matrix;

(3) quality filter mapping;

(4) demand amplification mapping; and

(5) decision point analysis.

The on-site mapping work was carried out over a three-day period and proved that each of the tools was of value in analysing the selected value streams. An example of the effective interplay of the tools was that the supply-chain response matrix suggested, as the key priority for the firm, supplier lead-time reduction. However, when the data from the quality filter mapping were added, it was found that the real issue was on-time delivery rather than lead-time reduction. Thus, if the supply-chain response matrix had been used on its own, it might have resulted in shorter lead time, but would have exacerbated the true problem of on-time delivery.

The work assisted the firm to conclude that, although it did not need to change, there was plenty of room for improvement, particularly regarding the relatively unresponsive suppliers. As a result, attention has been paid to the setting-up of a cross-function-driven supplier association[10], with six key suppliers in one product group area for the purpose of supplier co-ordination and development. In this supplier association there is an awareness-raising programme, involving ongoing benchmarking, of why change is required. In addition, education and implementation are being carried out using methods such as vendor-managed inventory, due date performance, milk rounds, self-certification, stabilized scheduling and EDI.

The company has found the ongoing mapping work to be very useful, and one senior executive noted that “the combination of mapping tools has provided an effective means of mapping the [company’s] supply chain, concentrating discussion/action on key issues”. Another described the work as “not rocket science but down to earth common sense which has resulted in us setting up a follow-up project which will be the most important thing we do between now and the end of the century”. Indeed, a conservative estimate of the savings that could be reaped is in excess of £10m per year as a result of this follow-on work.

Conclusion

This paper has outlined a new typology and decision-making process for the mapping of the value stream or supply chain. This general process is grounded in a contingency approach as it allows the researcher to choose the most appropriate methods for the particular industry, people and types of problem that exist. The typology is based around the identification of the particular wastes the researcher/company/value stream members wish to reduce or eliminate. As such, it allows for an extension of the effective internal waste-reduction philosophy pioneered by leading companies such as Toyota. In this case, however, such an approach can be widened and so extended to a value stream setting. This extension capability lies at the heart of creating lean enterprises, with each of the value stream members working to reduce wasteful activity both inside and between their organizations.

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