LEAN PRODUCTION AND MANUFACTURING PERFORMANCE IMPROVEMENT IN JAPAN, THE UK AND US 1994-2001

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Abstract

This paper reports the findings of a longitudinal study into manufacturing performance, lean production principles and buyer supplier relations in the Japanese, US and UK automotive industries. A total of 26 first tier component makers in the three countries were subject to detailed benchmarking exercises in 1994 and in 1999-2001. In each exercise data on labour productivity and quality performance were obtained, along with a series of quantitative measures indicating the extent to which each plant conformed to 'lean production' principles.

The results show that the Japanese plants improved their labour productivity by around 20 per cent between 1994 and 2001, whilst productivity in the US plants remained flat over the same period. All plants improved their quality performance during the period, but the Japanese plants retained their lead with an average external defect rate of 81 parts per million (ppm), compared to 111 ppm for the US plants and 416 ppm in the case of the UK plants.

Measures of leanness in the supply chain (inventory levels, delivery frequencies and so on) should be sensitive to any weakening of the inter-firm relationships that have historically characterized the Japanese auto industry. These measures showed no evidence of such weakening, although qualitative evidence suggested that a polarization of the Japanese auto industry may be occurring under the influence of foreign capital, with independent firms such as Toyota and Honda (and their suppliers) retaining a stronger 'Japanese' character than their counterparts who have entered into equity relationships with non-Japanese companies.

JEL Codes: L2, L6, M1

Keywords: Lean Production, Suppliers, Auto Industry, Japan

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Introduction

During the 1980s and through much of the 1990s the performance superiority of Japan's automotive companies relative to their Western counterparts was demonstrated repeatedly with respect to manufacturing (Schonberger 1982; Womack et al 1990; Oliver et al 1994, 1996) and new product development (Clark and Fujimoto 1991; Fujimoto 2000). "The "Machine that Changed the World" by Womack, Jones and Roos was published in 1990 and has sold hundreds of thousands of copies. This book ascribed Japanese manufacturing superiority to "lean production" principles, a distinct approach to the management of manufacturing centred largely on the Toyota Production System (TPS) the principles of which, it has been argued, are applicable to many other business processes as well (Womack and Jones 1996).

However, prolonged recession in Japan has taken its toll and Japan is no longer regarded as the economic paragon it was assumed to be 10 to 15 years ago. The reasons for this are not difficult to see. A number of Japanese financial institutions have collapsed, amidst widespread publicity. Several Japanese auto companies have experienced financial problems and have entered into tie-ups with foreign auto companies. The most public example of such a tie up was the merger between the French car company Renault and Nissan, but many other examples abound – Ford has had a substantial stake in Mazda for many years, but has increased this recently; GM has a moderate stake in Fuji Heavy Industries (Suburu); and Mitsubishi Motors are now part of the Daimler-Chrysler Group. Only Honda and Toyota continue to go it alone, though both have had, and in Toyota's case continue to have, joint venture activities with non-Japanese partners. Whereas in the 1980s and early 1990s much attention in writings on the auto industry focused on operational issues (manufacturing and new product development) more recently the focus of debate has centred more on strategic issues – acquisition and merger, systems supply,

modularity, e-procurement and exchanges and so on. Also, with the efficacy of the whole Japanese system called into question (Porter et al 2000), interest in Japanese firms as an example of a superior business model, to be emulated by the rest of the world, has declined. Consequently, performance comparisons between Japanese firms and their Western counterparts attract less attention than they once did. This is in many ways unfortunate. Although the focus of attention on Japan in the 1980s and 1990s may have been unduly operational, to the neglect of strategic issues, operational issues are still important and Japan still has lessons for the rest of the world. Furthermore, Japan's prowess for continuous improvement has been one of the features that delivered the manufacturing performance superiority so graphically illustrated by the studies of the 1980s and 1990s; has this been sustained in Japan, and to what effect? Japan's inter firm networks, once seen as a crucial source of Japan's competitive advantage, have been put under strain by prolonged recession and the influx of foreign capital. How are these faring in today's environment? Commentators such as Williams et al (1994) have argued that the success of Japan's auto industry, and Japan's particular social arrangements of production, were a function of an unusual set of historical circumstances. When long term growth came to an end, Williams et al predicted, Japan's car companies would start to behave in ways indistinguishable from their Western counterparts. Is this occurring?

The purpose of this paper is to address such issues via an analysis of relative levels of performance – and rates of improvement – amongst first tier automotive component manufacturers in Japan, the UK and the US. The study on which the paper is based is unusual in that detailed benchmarks of practice and performance were taken from a panel of plants in the three countries in 1994 and again in the period 1999-2001 when the measurement exercise was repeated with the same plants. This provides a rare glimpse of change over time at an unusually high level of detail.

Companies and Methods

As Table 1 shows, data were collected from 35 plants in the three countries in 1994 and from 29 plants in 1999-2001, of which 26 plants were common to both studies. The 1994 study also covered an additional 36 plants in France, Germany, Italy, Mexico and Spain, but these have been excluded from the analysis as we have no data on these plants for 1999-2001.

The data collection process involved an initial visit to each plant by members of the research team. At this visit the research team introduced the project, carried out an inspection of the plant and briefed the plant management on how to complete the questionnaire. The questionnaire was then left with the plant for a period of four to six weeks. This was a substantial document, with approximately 1,000 data fields, and typically took several days of management time to complete. The research team then made a second visit to each plant and reviewed the completed questionnaire with the plant management, a process which could take anything up to one day. Data collection during 1999-2001 followed exactly the same process. In most cases, staff turnover in the plants meant that the research team were dealing with a different set of respondents to those involved in the 1994 study.

The questionnaire covered seven main areas: plant performance; plant characteristics; process control; work organization; problem solving and improvement; relations with suppliers; and relations with customers. The main purpose of the questionnaire was to yield data that would permit systematic comparisons of performance between the plants in each product area, and profile the management practices of each plant to ascertain the extent to which lean production principles were in use. The questionnaire was constructed around the model of lean production presented in Figure 1.

Plant performance was measured by physical productivity, in terms of units per labour hour. This was calculated by taking the annual units of output of each facility and dividing it by the annual hours of labour

input. Adjustments were made for vertical integration, for the length of the working day, for overtime, absenteeism, and product complexity (for exhaust plants only). Quality was measured as defective units in parts per million (ppm) as reported to the plants by their customers (the car makers) over the same twelve-month period. The measures of management practice represented quantitative indicators of the use of lean production principles. The `leanness' of factory operations was measured by counting the hours of inventory of specific parts at various stages along the production process.
Continuous improvement activities were measured by asking about the presence or absence of suggestion schemes, the number of suggestions per employee and the use, membership, and activity rates of problem-solving groups such as quality circles. A similar approach was applied along the supply chain, on both the customer and supplier sides. Thus, data were gathered on the inventories of raw materials and finished goods, on delivery frequencies both by suppliers and to customers, on information exchange, joint problem solving activities between firms and so on.

Results

The results are presented under the following headings:

1. Manufacturing performance
2. Context – volumes, headcount, product variety
3. Problem solving and improvement
4. Buyer-supplier relations.

Manufacturing Performance

The first question that we set out to address was the relative productivity of plants in the three countries. Womack, et al (1990) claimed a 2:1 gap between Japanese vehicle assembly plants and their Western counterparts. Previous studies in the auto components sector (Oliver et al 1994, 1996) showed smaller gaps than this, although these were still substantial and virtually always in favour of the Japanese plants.

Table 2 demonstrates that the Japanese plants continue to outperform both the US and British plants in terms of labour productivity (minutes per unit). The Japanese seat plants are twice as productive as their US counterparts. The exhaust and brake plants show seven per cent and 15 per cent performance differentials respectively in favour of the Japanese over US plants. Overall, the British plants show an even greater productivity shortfall vis a vis the Japanese.

When the 2001 figures are compared to the 1994 performance figures for the same plants, a surprising picture emerges. The Japanese plants average an increase in labour productivity of 20 per cent, whereas labour productivity in the US plants has remained more or less static, and the British plants actually show a *decline* of 13 per cent. The net impact of this is a widening of the productivity gap between the Japanese plants and the US and British plants between 1994 and 2001.

The pattern of performance differentials is repeated with respect to defect rates. The Japanese plants average an external defect rate of 81 parts per million (ppm), some 25-30 per cent lower than the US plants and one fifth of the rate of the British plants. Compared to 1994 levels of quality, plants in all three countries show big improvements, in particular the British plants, though in the British case this was from a very high 1994 baseline of approximately 1,700 ppm. In 1994, US and Japanese levels of defects were similar; six years later there are signs that the Japanese may be opening up the gap again.

Context

What explains the apparent declines in labour productivity on the part of the UK and US plants? Declines in production volumes that have not been matched with a corresponding adjustment in staffing levels are an obvious explanation, but on average production volumes have risen, indicating that these plants are winners in terms of pressures for consolidation of production in the auto industry. In absolute terms production volumes in the Japanese and US plants were broadly comparable, and roughly double those of the UK plants. However, it

is striking that the expansion of output of the Japanese plants between 1994 and 2001 (+33%) has been achieved with only a modest increase to headcount, whereas the UK and US plants not only show substantial increases in volumes but also show substantial increases in numbers of employees. It should be noted that differences in vertical integration, product complexity, overtime, absence and non-working time all mediate in the relationship between headcount, volumes and labour productivity, and that the changes in labour productivity are not a straight function of changes to headcount and production volumes.

Product proliferation, as indicated by increased numbers of live part numbers, could be one explanation of static or depressed labour productivity, with its implications of shorter production runs, more set ups and associated logistics headaches. Fujimoto (2000) has reported efforts to increase the use of common parts across different vehicle platforms in Japan, and argues that this may be increasing the length of time spent in the planning stages of the product development cycle. The measure of product variety in this study was the number of live part numbers. Changes on this measure may be driven by strategies on the part of the component makers such as diversification of their customer bases, as well as increases in product variety on the part of the car makers that they already serve.

The Japanese plants show the greatest product variety, by a substantial margin – more than double the level of the UK and six times that of the US plants. As already demonstrated, production volumes in Japan and the US are broadly comparable, suggesting radically different volume/variety mixes in the two countries. Moreover, when the 1994 and 2001 figures are compared it is clear that the US plants are on a very different trajectory to the Japanese and UK plants, managing to reduce product variety by over 50 per cent whilst at the same time increasing volumes by about the same amount. This suggests progress with parts standardization and consolidation of production that is as yet absent in Japan or the UK.

Capacity utilization was also explored as a driver of changes in labour productivity. The US showed a slight drop in capacity utilization, and Japan and the UK showed increases in capacity utilization. This suggests that some of the boost to Japanese productivity is due to a better matching of output to capacity between 1994 and 2001. However, capacity utilization provides no clue as to why productivity of the UK plants has fallen.

Plants in all three countries show substantial falls in external defect rates between 1994 and 2001. However, there are differences in the patterns of reasons behind these defect rates, as Table 4 illustrates.

Amongst the Japanese plants, human errors in manufacturing stand out as the single most common cause of defects, in contrast to the UK and US where technical issues (for example machine problems) are the most frequent explanation of defects. Suppliers also stand out as a particular source of quality problems in the US, consistent with the figures on defect rates of parts coming in from second tier suppliers, shown in Table 6. In the 1994 study the US second tier performed poorly relative to the first tier and this pattern does not seem to have been addressed in the interim.

During the plant inspections in Japan, the most visible manifestations of quality improvement efforts were techniques and devices to reduce human errors – poke yoke. For example, since 1994 several plants had introduced devices such as infra-red sensors across the openings of line side bins that held small components such as fasteners, washers and other fittings. These sensors detected whether an operator had put his or her hand in the bin to pick up a fitting, and unless this had occurred prevented the work piece moving on to the next workstation. This reduced the probability of components being missed out of the assembly process. One seat plant had taken this a stage further by fitting covers to component bins – these covers were opened automatically with the arrival of the work piece. However, a bar code on the work piece controlled which covers were opened, thereby

eliminating the possibility of incorrect components being fitted to the work piece.

Given such innovations, it is somewhat surprising to see 'human error' appearing as the most significant cause of defects in the Japanese plants; this may be a testament to the progress that has already occurred in other areas, such as machine and supplier reliability.

Problem Solving and Improvement

The literature has made much of the bottom-up problem solving found in Japanese factories. This is manifested through employee suggestion schemes, in problem solving groups such as quality circles, and most generally under the generic banner of 'kaizen' activities.

Consistent with the patterns found in the 1994 study, the Japanese plants continue to show most activity on our measures of kaizen activity, as shown in Table 5. Japanese plants show the highest participation of production operators in problem-solving groups and the highest number of suggestions per head. Both US and UK plants show substantial increases in suggestions per employee, but this is from a relatively low base in 1994 and so the differential between the US and UK plants and the Japanese plants remains substantial. There was little change in suggestions per head in Japan over the period, suggesting a 'topping out' at around 25 suggestions per employee per year. In interviews, we explored the question of whether incremental process improvement could continue to yield the saving necessary to meet the cost reduction targets imposed by the car makers. Most respondents felt that incremental process improvements of themselves could not continue over long periods to deliver the required cost reductions and looked to value analysis and value engineering (VA/VE) techniques, and design-led cost reductions to drive out cost. One respondent commented that incremental process improvement over prolonged periods was akin to "trying to squeeze water from a dry towel".

Buyer-Supplier Relations

The relatively close relations between buyers and suppliers in the Japanese auto-industry, manifested by the keiretsu system, have been one of the most noted features of the Japanese system, and it has been argued, provide a major support to both the manufacturing and product development operations of the Japanese car companies by creating long term, high trust relations that facilitate co-operative behaviour such as joint cost reduction activities and problem solving and permit the tight coordination for JIT principles to work along the supply chain (Helper and Sako 1995; Lamming 1993; Macduffie and Helper 1997; Nishiguchi 1994; Nishiguchi and Beadet 1998; Sako 1992). The prolonged recession in Japan may be expected to affect some of these characteristics. A contraction in the market is likely to place long term collaborative relationships between buyers and suppliers under stress, as the game moves from being win-win to win-lose. There are certainly some signs that this is occurring. For example, in late 1999 Nissan announced that it was reducing its number of suppliers from 1,145 to less than 600 by 2002, selling its shares in all but four of its affiliate companies, and adopting Western-style competitive bidding for new contracts amongst its suppliers. Nissan parts suppliers reacted angrily to this:

> "Nissan officials are shirking their responsibility for having not been able to make cars that sell. Instead they are blaming us suppliers".
>
> "We shall be forced to stop purchasing automobiles from a company that coldly cuts us off" (*Daily Yomiuri*, 28 January 2000).

Ironically, the mentality of interdependence between companies, banks and suppliers, which has been seen as a strength of the Japanese business system, is now regarded as part of the problem, at least by Nissan's French partners. This had led some observers to argue that the traditional Japanese business system is breaking down and

converging towards a more "Western" (usually conceived of as market-based) model of buyer-supplier relations.

If this interpretation is correct, then the quantitative indicators of the closeness of buyer-supplier relations in Japan should exhibit signs of a loosening of relations. These figures are shown in Tables 6 and 7 (for links between the plants in the study and their suppliers) and Tables 8 and 9 (for links to car makers).

In 1994, the Japanese plants had approximately double the number of suppliers of their US and UK counterparts. Seven years later the number of Japanese suppliers had increased by 11 per cent (mainly due to increases in product variety). US plants showed much larger increases in the number of second tier suppliers (50 per cent plus) which is surprising given the US rationalization of product ranges noted previously. One possible explanation is that the continuing poor performance of the second tier in the US has forced the first tier extend their supplier bases in the search for more competent suppliers. This does not appear to have proved successful given the quality performance figures in Table 6.

On the two main indicators of supplier performance, on-time delivery and defect rates of incoming parts, Japanese plants continue to outperform UK and US plants. Since 1994 the latter show some improvement in terms of on-time delivery but virtually no change in terms of defect rates, accounting for the relatively high incidence of reports of 2nd tier supplier-induced defects in the quality performance of the 1st tier plants.

The measures of inventories and delivery frequencies, which we use to show the closeness of relations between the focal plants in the study and their suppliers (at least in a logistical sense) continue to show much tighter links between 1st and 2nd suppliers in Japan than in the US or UK. There is a 1:5 differential between Japanese and US plants and a 1:9 differential between Japan and the UK in terms of inventory levels. Japan and the US both show comparable falls in

inventory levels over the seven year period, in the order of 25 per cent.

Thus, there is little evidence of a loosening of relationships at the 2nd tier/1st tier interface in Japan during the period covered by the study. It may of course be that the logistics-based indicators of closeness are not sensitive to the changing commercial arrangements (such as the awarding of contracts on the basis of price-based competition) that are unfolding around them. Alternatively, it may be that any such changes are more marked at the car maker/1st tier supplier interface where the impact of influences such as foreign capital are most evident. The results pertinent to this are shown in Tables 8 and 9.

The data on the car maker/1st tier interface show a similar pattern to that already observed at the 1st tier/2nd tier interface. Japanese plants show much better performance in terms of on time delivery (by a factor of over 40), have far lower inventories and more frequent deliveries compared to the UK and US plants. All these measures indicate a much tighter coupling between car-makers and suppliers in Japan than is found in the other two countries. Moreover, it can be seen from Table 9 that the Japanese plants show more improvement on these measures between 1994 and 2001. Of the three countries, the Japanese plants show the least change in terms of numbers of car makers that they serve, again indicative of stability and continuity, rather than change and revolution, in Japanese buyer-supplier networks.

Conclusions and Implications

What do these patterns of change in Japan, the UK and US demonstrate? First, they show that, at least as far as these auto component plants are concerned, Japan has not lost its edge over the US and UK in terms of manufacturing performance. The Japanese plants have continued to make improvements in terms of labour efficiency and still lead their US and especially their UK counterparts, by a significant margin. Labour productivity in the US and UK plants has been more or less static (and actually shows a decline in the case

of the UK). Although on average production volumes in the plants in all three countries have risen, Japan has managed this with a much smaller increase in headcount than either the US or UK plants, and without a major rationalization of product ranges. The US plants have made considerable progress in rationalizing their product ranges.

Plants in all three countries have made significant progress in reducing the proportion of defective products that reach their customers (that is, the car makers, in the case of this study). Japan continues to lead the US in quality performance by a margin of around 30 per cent, whilst the UK trails a distant third. Defects in incoming parts are a particular problem in the US, suggesting that the manufacturing reform that has been occurring amongst the car makers and first tier suppliers has still to penetrate the second and third tiers.

The continuing poor performance of US second tier suppliers is striking. In 1994 we noted that US first tier suppliers were struggling to cope with poor quality and delivery performance from their second tier suppliers, and that their role as a quality 'filter' added considerable strain and cost. These findings were acknowledged and confirmed by the industry at the time but the subsequent period has seen little improvement. One impediment to improvement in suppliers' performance appears to be that purchasing decisions are taken primarily on a cost basis, by headquarters functions unfamiliar with the operational and logistics requirements of their own plants. Given the sustained, and in some areas increasing, performance advantage of the Japanese plants, it is precisely in areas such as these that renewed interest should be taken.

The measures relevant to the closeness of buyer supplier relations largely present a picture of continuity, rather than change, in Japan. The tight logistics symptomatic of close social relations between buyers and suppliers have if anything become tighter over the last seven years. Of course it may be that changes in the commercial relations between firms do not affect such operational details, though this would run counter to what has been the accepted wisdom through

much of the 1980s and 1990s, namely that it is the very existence of tight social relations that permits and facilitates operational excellence. An alternative explanation is that changes in social relations are occurring, but that the lag inherent in any such changes is obscuring this.

The results of this study also point to an apparent paradox. The Japanese plants clearly perform very well operationally, but a more macro economic analysis does not present the same picture of success. The largest component firms in the world are predominantly US and European firms – only one or Japanese firms figure in the top ten. Similarly, many Japanese firms have been experiencing financial problems of one sort or another and recourse to foreign capital has been one response to this. Detailed treatment of this issue is beyond the remit of this paper, but one interpretation of this is that Japanese suppliers are suffering due to the structural features of the Japanese auto industry – specifically a relatively large number of car and associated component makers, with relatively high dependency relations between car makers and their main component suppliers. This structure facilitates cooperation between car makers and suppliers, but means that the risks faced by the component makers are relatively concentrated. In the event of a prolonged recession, as Japan has faced, such a structure may more rapidly lead to financial problems than one in which component makers can spread their risks across a wider base of car makers, and possibly car-producing regions. In this respect, the very conditions that encourage operational excellence through greater intimacy between buyers and suppliers may work against the spreading of risk – and vice versa.

This said, the economic problems experienced by Japan at a macroeconomic level should not distract from the continuing lessons that may be gleaned from operational assessments of Japanese manufacturers. In difficult circumstances, Japanese plants have continued to improve their operational performance. The concept of continuous improvement is one of the most significant components of the Japanese model of manufacturing; the evidence reported here

suggests that this concept remains an enduring feature of Japanese manufacturers and it remains an area where Western manufacturers may have much to learn.

TABLES AND FIGURES

TABLE 1: JAPANESE, UK AND US PLANTS (1994 and 1999-2001)

	1994	**1999-2001**	**Number Common to Both Studies**
Japan	9	10	8
UK	12	9	9
US	14	10	9
Total	35	29	26

FIGURE 1: THE LEAN PRODUCTION MODEL

	Inside the Factory	**Along the Supply Chain**
Flow	JIT, low inventories of WIP, 'pull' systems of production control, simple work flow, team based work organization, visual control	JIT deliveries, low inventories of incoming parts and finished goods
Error Prevention	High process control, work standardization, poke yoke, design for manufacture	Joint planning, design and development, high visibility of processes along the supply chain, schedule stability, staff exchanges
Improvement	Problem solving and continuous improvement groups, suggestion schemes	Joint problem solving and cost reduction, supplier associations

TABLE 2: PRODUCTIVITY, QUALITY AND CHANGE OVER TIME 1994-2001

	Japan	**UK**	**US**
Minutes of direct labour to produce a unit, 2001:			
Seat plants	45.5	83.3	90.1
Exhaust plants	7.5	9.8	8.1
Brake plants	5.5	13.8	6.5
Average change in labour productivity 1994-2001	+20%	-13%	-2%
External defect rates (ppm, 2001)	81	416	111
Change in defect rate 1994-2001	-58%	-75%	-35%

TABLE 3: CONTEXT AND CHANGE OVER TIME

	Japan	**UK**	**US**
Headcount (direct and indirect)	275	240	306
Product variety (excluding exhausts)[1]	357	145	63
Change in production volumes since 1994	+33%	+62%	+53%
Change in headcount since 1994	+11%	+49%	+55%
Change in product variety since 1994	+12%	+45%	-52%

[1] Due to special circumstances (high aftermarket requirements, options of shipping part-products this measure is prone to unreliability for exhaust plants and has therefore been excluded)

TABLE 4: SOURCES OF DEFECTS

	Japan	**UK**	**US**
Design issues	7.5%	10.3%	7.4%
Suppliers	8.0%	15.7%	25.0%
Manufacturing - technical issues	7.9%	36.9%	41.9%
Manufacturing – human issues	68.8%	33.5%	21.9%
Other	7.8%	3.6%	3.8%

TABLE 5: PROBLEM SOLVING AND IMPROVEMENT

	Japan	**UK**	**US**
% of operators involved in problem solving groups	88.1%	70.0%	52.0%
Suggestions per head	24.5	1.9	4.0
Annual target per operator	19.3	2.0	13.3
% of suggestions from production operators	69.0%	87.4%	42.3%

TABLE 6: SUPPLIER RELATIONS, 2001

	Japan	**UK**	**US**
Number of suppliers	78	32	56
Incoming defect rate (ppm)	463	3,861	7,752
% of late deliveries from suppliers	3.5%	4.4%	12.3%
Hours of incoming parts	10.6	93.8	55.4
Frequency of delivery from suppliers (every x hours)	6.1	41.0	25.5

TABLE 7: INDICATORS OF CHANGE OVER TIME IN 1ST TIER/2ND TIER RELATIONS

	Japan	**UK**	**US**
Number of suppliers	+11%	+7%	+51%
Hours of incoming parts	-26%	-10%	-25%
Frequency of deliveries from suppliers	+8%	-4%	+53%

TABLE 8: CUSTOMER RELATIONS, 2001

	Japan	**UK**	**US**
Number of customers	3.0	2.4	2.3
% of late deliveries to customers	0.1%	4.8%	4.2%
Finished goods inventory (hours)	2.4	69.6	30.0
Frequency of delivery to customers (every x hours)	4.1	15.5	10.2

TABLE 9: INDICATORS OF CHANGE OVER TIME IN 1ST TIER/CAR MAKER RELATIONS

	Japan	**UK**	**US**
Number of customers	+3%	+42%	+13%
Hours of finished goods	-79%	-1%	+18%
Frequency of delivery	+20%	-30%	+12%

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