Henry Ford's just-in-time system

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Received May 1994
Revised July 1994

Schonberger[1], Ohno[2] and Shingo[3] have described the differences between Western and Japanese approaches to manufacturing management. Their comparisons of the two have emphasized differences; often to the great disadvantage of contemporary Western approaches. Ohno[2, p. xiv] called one the "Toyota Production System", and the other the "Ford Production System" as a means of distinguishing between the two. Ohno believes that Ford's system evolved in ways that Ford himself would not have pursued, and a review of Ford's own views[4,5] and contemporary discussions by Bornholdt[6], Arnold and Faurote[7], and Faurote[8] of Ford's operations support him. Henry Ford was a proponent of many of the ideas central to just-in-time (JIT) systems. The environment in the early 1900s and 1920s was very different from today's; but many of the features of JIT systems were known then and practised by Ford consciously within the framework of an integrated manufacturing system.

The system Ford used for the Model T is one radically different from that criticized by Schonberger[1], Ohno[2] and Shingo[3]. The main features of what can be called Ford's model T production system (MTPS) to distinguish it from the modern one, and their similarities to those of Toyota's JIT approach, will be described. In a foreword to a reprint of Ford's *Today and Tomorrow,* Bodek[9, p. vii] remarks that Ohno suggested that people seeking the origins of his ideas should look to Ford since "...he learned it all from Ford's book". This article provides an overview of Ford's policies and activities. It does not give a "snapshot" view of his policies at any one time, or of their implementation in any specific facility. A broader appreciation of Ford's ideas is the objective, and a historical perspective covering the whole of its development is necessary. No one point would be adequate since Ford's system evolved in a number of factories, and over a 30-year period before he fundamentally shifted to mixed model production and away from his basic manufacturing philosophy.

The MTPS was composed of a number of complementary and mutually supporting elements that provided an integrated and highly focused system. The modern "Ford" system so criticized by proponents of JIT systems is not the one Ford conceived and implemented; it changed without fundamentally adapting to new circumstances. Ford's genius in originating the system seems beyond dispute, but so too is his failure to adapt as the market changed. Even by the late 1930s the inherent problems with Ford's organization and with Ford's manufacturing system became evident, and while Henry Ford II was able eventually to resolve the organizational difficulties, the fundamental changes

International Journal of Operations & Production Management, Vol. 15 No. 12, 1995, pp. 59-75. © MCB University Press, 0144-3577

needed to adapt the manufacturing system to its changed environment were not recognized.

Quality systems

A dominant feature of JIT manufacturing systems is their emphasis on quality. Such an approach cannot operate successfully without high levels of quality. The emphasis on quality was also a central feature of Ford's MTPS and the quality levels attained were a remarkable achievement for that period. The difference between fit and finish is a distinction generally lost on many modern readers. Ford recognized that high volume production was dependent on having component parts which were truly interchangeable. Without this critical feature mass production would be both difficult and costly; and a production line requiring invariant operation times would be impossible[5, p. 140]. It is now taken for granted that well-finished pieces of work will fit together, but this was not the case even at the turn of the century. Although the problem of interchangeability is widely thought to have been resolved by Eli Whitney at the start of the 1800s, it remained problematical until the early 1900s. Standardization was not achieved for most of the nineteenth century, and what mass production did occur was specialized and achieved in spite of the difficulties caused by nearly interchangeable parts. Hounshell[10] describes the development of different segments of American industry through the nineteenth century and charts the progress of interchangeability to its fulfilment with the automobile industry in the early 1900s. Only then did a secure foundation actually exist for mass production more generally.

The assembly line's development in 1913 was just as dependent on quality as JIT is now. JIT systems emphasize quality and each employee's responsibility in achieving and maintaining it. Ohno's view[2] of Ford's system portrays quality in it as the responsibility of inspectors, with production staff taking no interest. The key distinction being that operations staff in the JIT system detect and rectify errors as they are being made while the Ford system continues producing sub-standard items until the batch finished production. The key difference between the system criticized and the MTPS lies in the batches. The MTPS produced a single product continuously – batch production of mixed models only came later. The MTPS relied on inspectors to ensure that the finished product met its specifications and went much further to ensure quality by an intensification of the inspection process. Ford and Crowther[5, p. 100] note that 3 per cent of his employees were inspectors, a high proportion of the total workforce and one that was imaginatively employed. Ford used special "machine inspectors" to effectively provide quality control at the much same points and in the same ways as in JIT systems. Arnold and Faurote[7, p. 99] describe the activities of these inspectors: "Machine inspectors enough are placed in each department to cover all operations ... at frequent intervals, so that no faulty operation shall proceed for any great length of time". The role of these inspectors was to inspect the production *process* to ensure quality in the products made. Having special inspectors undertaking this task frequently is

not as good as having all staff performing such inspections constantly as is the aim of JIT, but it is a fair recognition of the need for such quality controls and an appropriate response.

Arnold and Faurote[7, p. 100] also mention Ford using "travelling inspectors" to inspect supplier's plants to discuss issues of mutual concern, but they say little about that aspect of Ford's quality management. Ford himself makes a telling point:

> It would make no difference whether one company or one individual owned all the factories fabricating the component parts of a single product ... *if only all adopted the same service methods*[4, p. 52-3, emphasis in the original].

While it is unclear whether Ford sought to have his quality management methods adopted more widely as Toyota has done with its suppliers this does show Ford's awareness of the interdependence of businesses and their need for consistent operations. Suppliers had to meet quality targets since the transportation system could not quickly resupply any rejected supplies. Ford makes the point that the MTPS had the capability of producing all the components necessary to protect themselves against supply failures. Productive capacity rather than safety stocks were Ford's response to supply uncertainties.

Ford recognized that quality was critical to increasing production and efficiency and much of his focus was on attaining the levels necessary to allow mass production. Quality was critical for *manufacturing* needs. The parts simply could not be put together if they did not fit properly. The assembly line was the capstone of this process – it could not exist without high quality parts, and it built on practices that took decades to develop. Consistency of performance was critical for interchangeability. Materials, men and machinery all had to operate within rigorously identified limits if the system and its products were to function properly. Ford played a key role in recognizing this and in identifying a suitable product for the market and developing a manufacturing system to deliver it.

Ford did not simply inspect work to remove quality problems. The system was designed so that operating staff would have relatively little and strictly limited influence on the quality and volume of work performed. Wherever possible Ford sought to mechanize the effort so that unskilled and very narrowly trained staff would be able to cope with the demands of the job[11]. Ford comments that machinery would be used to do the hard work wherever possible, the system eliminated both the "heavy" and the "fine" work. Staff no longer had to slave at gruelling tasks, but skilful and time-consuming work was eliminated too. The assembly line gave Ford a mechanism for ensuring a very high level of control over the work that his employees performed – a mechanism that was designed considering the nature of the labour force. Ford employed people who were unskilled and poorly educated, few were high school graduates; and, in many cases the company had to teach immigrants English and other basics. The people were the weakest link in producing the quantities

needed to the desired quality at the times required. The system was designed to minimize the potential for error and implicitly limited its requirements to the lowest common denominator. Ford often remarks that staff could and did rise above these levels through initiative; but he was generally very defensive about the control which the system had over the activities of the people in it.

Product design

The Model T is Ford's best known and most influential product. Ford succeeded because he recognized a need for an inexpensive, reliable automobile and exploited it. Ford's ideas reveal his approach to design as an engineer who differed from other automobile manufacturers. He did not regard big as synomous with strong, and sought to eliminate waste in unneeded weight. Large, heavy cars were undesirable: "I was working for lightness; the foreign makers have never seemed to appreciate what light weight means"[4, p. 34]. A comment heavy with irony for those who remember the large "gas-guzzlers" of the 1950s and 1960s and their smaller, lighter European and Japanese competition. It is quite clear that Ford[4, p. 19] believed that the objective of manufacturing design was to deliver the best possible product to the customer as economically as possible. He believed in providing "service" to his customers and that a long-term perspective was required. The Model T was not only an integral part of the manufacturing system, it was the foundation on which the system was built.

This may be seen best in Ford's fixation on producing a single product: "a car that would meet the needs of the multitudes. All my efforts were then and still are turned to the production of one car-one model"[4, p. 67]. Ford goes on to describe the evolution of the various earlier models to reach their culmination in the Model T that embodied all he knew about the product and the market. Lacey[12, p. 127] considers that the Model T was "state of the art" and offered an unbeatable combination of reliability and innovation when introduced. Ford's dedication to a single model is clear: "I do not believe in starting to make until I have discovered the best possible thing"[4, p. 16], and this attitude was tempered by a progressive attitude towards improvements: "… when a model was settled on then every improvement on that model should be interchangeable with the old model, so that a car should never get out of date"[4, p. 48]. The key point in this design strategy is its implications for manufacturing management. Ford clung to this single product ideal long after the market for cars had developed to create desires for a wider product range and openings for General Motors to exploit. One abiding motivation was that having a single product produced continuously in bulk allowed Ford to achieve very efficient production. The Model T was produced for almost 20 years, with some 8,000 a day made at its peak[5]. A standardized design was necessary for Ford to realize economies of scale in production, but it also had to allow for product improvements. Ford saw product improvement as critical for success and recognized that service to his customers made a stable basic design an equally important foundation.

Where the product design was essentially fixed the role of manufacturing was to create competitive advantage: "Where most manufacturers find themselves quicker to make a change in the product than in the method of manufacture – we follow exactly the opposite course"[4, p. 16]. Ford believed in designing a "universal" car fit for a mass market for a very long time, and keeping it modern through incorporating improvements as they occurred. This environment in which Toyota's JIT systems arose differs significantly from that of Ford's assembly line as Galbraith's comparison[13] of the introduction of the Model T in 1908 and the Mustang in 1964 describes. Ford was producing what was effectively a "commodity" in bulk for a mass market without serious competition initially. Toyota and other modern producers are producing much smaller volumes of differentiated products in more sophisticated and competitive markets. Much of the comment favourable to JIT systems focuses on its adaptability for rapid responses to markets and decreasing product life cycles.

Ford's system was ideally suited to the requirements of its time and his desire to produce single model in bulk forever eliminated many management problems. There was no need for economic order quantities, large on hand stocks; or, indeed, for rapid set ups. A production run of millions of units using dedicated facilities over almost two decades made such considerations irrelevant. One notable focus for Bornholdt[6], Arnold and Faurote[7] and Faurote[8] is their use of the term "continuous" when discussing manufacturing; they clearly thought such an approach was significant – an ideal for manufacturers to aim at and achieve. A continuous approach to manufacturing created operational problems of its own: balancing throughput with demand, capacity planning, communications and transportation management, etc.

The strategic consequences of this policy were significant because Ford's system was inflexible. It took six months to change models from the Model T to the Model A. Hounshell[10] believes that Ford lost $100 million during the change and spent $18 million on tooling alone. The factory was virtually torn apart in this process. Of its 43,000 machine tools some 32,000 were specialized and dedicated to the Model T, and half had to be scrapped and the rest modified. Lacey[12, p. 366] presents somewhat different figures – estimating that 16,000 machines had to be rebuilt and another 4,000 bought, with a total cost of changing models to Ford of about $250 million. By either view the changes took substantial time, money and effort to implement. Even with these major changes Ford only shifted production from one model to another. Only after another several years did Ford adopt the annual model change under pressure from General Motors. Ford's earlier strategy was to produce a good product at a fair price to stimulate demand, and then take advantage of standardization and high volume production efficiency. Ford's single product manufacturing advantages were also its marketing weaknesses. Sloan[14, p. 165-7] describes a meeting where even at General Motors the annual model change was resisted because it was thought to delay product and process improvements. Only in the

mid-1930s did Ford fully embrace a marketing lead model change design strategy that undermined the foundations on which its manufacturing system was built.

Process design

Ford's MTPS was one in which his marketing strategy and ideas about product design dictated that no changeovers between products were contemplated. The manufacturing system was designed specifically for the continuous production of a single product in bulk for long periods. The important aspect of this perspective is the recognition that both the MTPS and JIT used highly specialized equipment; in the MTPS to maximize throughput while JIT looked to maximize flexibility. A key element in JIT systems was developing specialized equipment to allow rapid changeovers between products. Set-up times were reduced from hours to minutes. Current developments may allow virtually instantaneous changeovers as Shingo[3] describes. This equipment has increased the capabilities of Japanese manufacturers to allow significant cost advantages over American and international competitors in the intermittent production of mixed models.

Ford too found that they needed to develop much of the equipment that was used in their factory. The manufacturing technology available then was not designed for high volume, continuous manufacturing so much of the development work was necessarily undertaken by Ford's own engineers. Ford[4, p. 85] and Arnold and Faurote[7, p. 307] report a story of a machine tools supplier's incredulity at a Ford engineer's specified output – to do in an hour what was the norm for a day's work. A quandary that was resolved only by the engineer's already having had a prototype built and operating at the required level. Ford employed many highly skilled staff with the primary purpose of developing equipment to make operating staff more productive. Ford dominated the automobile industry because this equipment increased their capabilities and allowed significant cost advantages over other American and international competitors in the continuous production of a single model.

Ford also looked at set-up time reduction as a means for increasing the throughput of his system. Although his system did not require for a set-up to be broken in order to change between models it did require individual items of work to be set up for various manufacturing operations. The key point here is recognizing that while Ford's MTPS did not need to change dies or tooling for different products or models it did need to change the *pieces* being worked on. A great deal of effort was then devoted to that aspect of speeding up the handling of material and tooling. Ford[4] and Arnold and Faurote[7] comment several times at length on developments that Ford used to shift from single unit machining to batch machining, and from sequences of single operations to simultaneous, multiple operations. Ford[5] also remarks on various techniques used (like two-way, forward and reverse feeds for drill presses) to virtually eliminate some work set-ups. Speeding up and ensuring the proper placement

of material provided Ford with significant productivity gains in both volume and quality of output. These gains are directly analogous to those obtained with JIT systems. Much of the analysis of machine operation and set-up is strikingly similar to activities Shingo[3] describes.

Facility layout and work in progress

Ford's objective in developing the assembly line was to increase the efficiency of production. Ford was a relatively high volume producer of automobiles before the Model T was introduced and a number of specialized techniques were employed to achieve this output. Even so, these methods at their most efficient were not capable of providing the volume of production that Ford required. Arnold and Faurote[7, p. 25] note that in 1913 Ford employed up to 1,000 people simply to move material in his factory, an occupation that was to be virtually eliminated in a new building with an improved layout and with mechanized and gravity-based materials handling systems. Ford discovered that great economies could be made by moving stocks to the assembly staff rather than having them leave their workplaces to get materials. He also noted that economies could be made by providing them with all the necessary tooling and eliminating toolrooms[5, p. 100]. The capital cost was more than made up by labour savings since staff did not have to leave their work positions and queue for material or tools. This recognized explicitly the desirability of delivery of materials to the workplace, and in their new factory: "… the rule at Highland Park was that men never moved from their work, the work came to them"[12, p. 138]. The great emphasis placed on efficiency in transporting materials in Ford factories seems to have been the motivating factor that underlay the development of the assembly line. Ford later went even further and designed his factories to allow delivery direct to the production line: "… trucking and handling are virtually eliminated … the greatest distance any material has to be trucked is twenty feet, this being the distance from the incoming freight car to the first conveyer"[5, p. 100]. This clearly anticipates and may have even inspired Toyota's efforts to have material delivered directly to its assembly lines.

Lacey[12, p. 139] described the approach before 1913 as a process line which: "...embodied calculated, progressive movement, but there was no continuous flow". The assembly line largely appears to have been founded on making the earlier manual approaches more structured and rigorous first; and then, mechanized and continuous. It was first instituted on 1 April 1913 in a manually driven, worker paced form, and soon developed to a mechanically driven form and spread throughout other suitable operations in the factory. The impact of the assembly line was to reduce direct labour input from 728 minutes to 93 minutes per car within one year[12, p. 159]. Ford continued to focus a great deal of attention on the movement of materials through the manufacturing operations. Bornholdt[6] succinctly summarizes the Ford approach in his article's title "Continuous manufacturing by placing machines in accordance with sequence of operations". Other contemporary commentators

(Arnold and Faurote[7]) describe how the layout follows the natural sequence of processes required to produce the various components and assemblies. Faurote[8] noted that Ford engineers conserved space by using very detailed floor plans and positioned equipment so that "… when a … mechanism comes into the factory … it is placed in such a position that the material coming from the last operation will be as nearly as possible in the exact position for the succeeding one"[8, p. 305]. It is also startling to see that the interaction between facility layout and work in process inventories was well appreciated even in 1913:

> There is another advantage in placing the machines in accordance with the sequence of operations; even though some machines are not worked to their full capacity the amount invested in them is well paid for from the fact that it is not necessary to carry nearly so much stock as when the machines are grouped according to their classification. Each group or department alone would in that case need to have nearly as much raw stock to work with as is necessary with this method to operate the whole series of machines to complete the part[6, p. 1678].

The high volume made efficient handling of material critical and left little room for work in progress to accumulate[4, p. 166]. Arnold and Faurote summarize these ideas: "the more work in progress, the less floor space available for doing the work". Ford comments at several points on waste in manufacturing but his views on layout are significant: "they [machines] are scientifically arranged, not only in the sequence of operations, but to give every man and every machine every square inch of space that he requires and … not … more"[4, p. 113]. Ford was extremely conscious that space in his factory was valuable and sought to exploit it as fully as possible without giving any more to work in progress than was necessary. It seems to have been an unwritten assumption that little room would be provided for work in progress inventories that were not being actively processed. Faurote could not have said "exact position" if material were just added to a large pile of work in progress. Ford[4, p. 90] emphasizes "dividing and subdividing operations, keeping the work in motion – those are the keynotes of production", in a perspective that leaves no room for excessive or idle inventories.

Nevertheless, a cautious note is needed too because Ford did not operate a JIT system although many of the statements sound very close to implying that one was in place. For example, Arnold and Faurote[7, p. 71] remark that "the Ford shops manage to face a constant shortage probability – perhaps it might be said that the real condition is that of actual shortage of components constantly – and yet escape serious delays". Ford, in 1913, operated with a policy dictating minimum and maximum levels; these seem to have allowed a "supply" of 3,000 to 5,000 components, enough for two to three days' production requirements[7, p. 63]. This seems very different from a true JIT system, but is somewhat ambiguous since work in process and inventories held in stockrooms seem to have been lumped together. Having this supply available in the factory should not imply that they were all in stockrooms, though that may have been the normal source as Arnold and Faurote[7, p. 64] imply:

> When a Ford car assembled-component assembler suddenly discovers that his requisition on finished stores for components wanted is not filled because there are no such components in finished stores, no grand conclave of factory accountants is summoned.

The system produced components to be held as a buffer stock between operations, and when these buffers were depleted as frequently happened, the system then relied on "shortage chasers", one of whom "boards the department drifting within the sound of breakers, seizes the helm of component production, and pilots the department into smooth water again – sometimes but barely escaping the surf-line …"[7, p. 64] – an analogy similar to the river and rocks often seen in discussion of JIT systems.

Arnold and Faurote[7] show many photographs of the Ford factory in 1913 with obvious work in progress stocks. Schonberger[1] shows only a few photographs of Kawasaki's operations in the 1980s. Comparisons between these do not reveal much difference between the work in process seen in them, allowing for size differences between the Model T's in one and the motorcycles in the other. Nakane and Hall[15, p. 88] state that Kawasaki operates with "about a week's" work in progress stocks. It may be impossible to tell what Ford's WIP stocks were in the MTPS, but they seem broadly comparable with those utilized under JIT approaches. The floor plans shown in Arnold and Faurote[7, foldout insert at p. 24] also reinforce the impression that stockrooms were small relative to the floor space devoted to production activities.

Another detail that reinforces the impression of occasional JIT operations are various "shop tags" used by the clearing house clerk. Several different ones used in 1913 are shown and discussed by Arnold and Faurote[7, pp. 68-71] with a distinction between the usual ones and those indicating an expedited or rush movement. Although these tags might be compared to the *kanbans* shown in Ohno[2] they are rather different and still represent a "push" system. These tags were used to control the movement of materials within the Ford factory, some were clearly used to direct stock to assembly departments while others allowed stock to be sent either to finished-stock storage or to assembly. The normal mode of operation is not clear from Arnold and Faurote's discussion: finished-stock storerooms may have been used for overflow, or they could have been a temporary holding stage in the normal work flow. The "rush" tags discussed are more clearly analogous to *kanbans* since it seems that these tags were used by the "shortage chasers" to rush material out to departments to prevent their running short of work.

Even before the introduction of the Model T Ford anticipated later developments in supply chain management by negotiating long term contracts with suppliers so the factory would carry less stock[10]. Ford's own views on purchasing and controlling inventories are significant too:

> We have found in buying materials that it is not worthwhile to buy for other than immediate needs. We buy only enough to fit into the plan of production, taking into consideration the state of transportation at the time. If transportation were perfect and an even flow of materials could be assured, it would not be necessary to carry any stock whatsoever[4, p. 143].

Transportation was a major problem for Ford and many problems arose in dealing with variations in it. The transportation infrastructure was much less extensive, flexible or reliable than now, and this created many difficulties for Ford. Transportation inventories were a major consideration for production planning and strong measures were needed to manage them:

> When a delivery has been ordered on a purchase contract … a "follow-up" assistant … keeps after it until shipment is made … supervision of the movement then passes to the traffic department … until the goods arrive … they then enter into the custody of the material department by whom they are routed to the exact point of use in the shops. In case of over-accumulation of stock at any point the routing clerk … directs a new place of delivery until the stock has been reduced[7, p. 35].

Even in 1913 the magnitude of this task was substantial since it involved controlling the 175 incoming rail cars with components and materials, and the 75 outgoing with finished goods, that were handled every day. The difficulty of this task can be better appreciated if we recall the cruder and slower transportation and communications systems with which Ford had to work. Initially, motorized transport did not exist and the telephone system was time consuming and difficult. These problems are easily overlooked today and Ohno[2, p. 95] writes that "The difference is that, while Sorensen (Ford's production manager in 1910) worried about warehousing parts, Toyota eliminated the warehouse", without recognizing that Ford with the MTPS later approached the same objective under far greater environmental risks and constraints. Ford[4,5] also eliminated the warehouse because the volume was just too great to store, even temporarily.

Schonberger[1] notes that the Kawasaki JIT system moved away from conveyors to handling material in racks holding fixed quantities. This too is mirrored in Ford's MTPS. It used mechanical conveyers extensively internally to control the flow and pace of work but this mechanism was not available to manage shipments from external suppliers. In these cases rail cars were the mode of transport and these were most effectively managed by using "standard carloads". Shipments would be composed of a set number of specific items dictated by the space available per car and the size of the items shipped. This economized on both transportation and on simplification of re-ordering and handling of shipments[5, p. 114-5]. Ford used 25 different "standard carloads" in reordering stock instead of a virtually infinite number of mixed loadings. The attention that Ford paid to these shipments also reveals how low the work in progress stocks were: "Men are stationed at junctions and other points throughout the country to see that cars are not delayed … if a car is overdue more than one hour, the fact is known at headquarters"[5, p. 115]. Such accuracy in monitoring transportation would not have been necessary if the MTPS held extensive stocks.

Ford[5, p. 115] was so dedicated to controlling transportation inventories that they bought a railroad and ore ships. By acquiring control over the transportation system they could then ensure a better service in meeting delivery and manufacturing schedules. This helped in reducing the manufacturing cycle from 22 to 14 days, and then with other efforts, to just over three days.

Ford[4, p. 175] recognized that capital was tied up in inventories and saw them as a prime source for extracting money for reinvestment elsewhere in the business.

Continuous improvement

The usual perspective focuses on the production system's ability to move quickly in improving its operations. Ford focused on the system's adaptability to absorb new techniques and methods. Ford and Crowther[4, p. 79] note that there were innumerable and constant changes to their factory and its operations. These improvements were not just imposed from above but were actively pursued by all employees[4, p. 94; 7, p. 308]. The MTPS was efficient, and rapidly developed new processes and methods to allow high volumes of a standardized product to be economically produced. Both the product and the processes developed and improved significantly over their lifetimes. There are two distinct elements to responsive manufacturing systems – the ability to change the products made and the ability to change the processes or how the products are made. JIT systems are capable of adapting the processes used in making products, and they are able to rapidly adapt to changes in products. A key advantage is the system's ability to shift production rapidly to newer models. Ford's attitude towards product design and development does not conform to such a perspective; process improvement was something he favoured and pushed forward relentlessly; but model or product changes were fiercely resisted. Ford would probably have suggested that such rapid and major changes in the product represent an example of a "throw-away" society's wasteful habits. It is ironic that Japanese manufacturing systems founded on an avoidance of waste may themselves contribute to rapid product obsolescence. Ford's system was highly responsive too, and although it changed its product relatively slightly it did alter the production systems, materials used and the technology significantly.

Western approaches rely on inventories to stabilize operations and these often remove incentives to improve Japanese operations eliminate inventories and can readily identify and remedy difficulties[1]. Continuous improvement is an integral element in JIT systems and contributes a quality focus not found in Western practice. While this criticism may be true for modern practice with mixed models and batch production its applicability to Ford's MTPS is doubtful. The continuous nature of Model T production would make bottlenecks or quality problems obvious immediately, and have critical effects if not quickly remedied. The Model T was produced for several years starting in 1908 using increasingly more refined methods before Ford built an assembly line for it. The introduction of the assembly line in 1913 inaugurated a period of rapid development in several areas at Ford. The product was continually upgraded and new manufacturing methods and techniques were constantly being suggested, tested and implemented. The volume of changes and the rate at which they occurred was phenomenal. Increases in productivity and output, improvements in the product and reductions in cost were simultaneously

achieved from the introduction of the model T in 1908 through the 1920s when it had to be replaced[4, p. 79; 5, p. 243]. The Model T was in production for almost 20 years during a time of rapid technical advancement; and, although it became dated in the later years, it could not have survived so long without continual improvement.

Ford's introduction of the assembly line was a major innovation. His inspiration was drawn from many sources, but the most intriguing one is his[4, p. 81] comment that a "dis-assembly line" in a slaughterhouse was its primary source. The key insight was that parts might be attached to automobiles as easily as "parts" were detached from carcasses as they moved along a conveyer. This could be an apocryphal story but it shows Ford was open to a wide range of influences and was prepared fundamentally to change the ways in which the factory operated.

Finance

Differences in the financial organizations and accounting practices found in Japan and the West have contributed to differences in the assessment and operation of manufacturing systems[16]. Ford never paid much attention to this aspect of his business, his two books reveal his negative attitudes towards finance and very poor opinion of accountants generally. At one point he summarily dismissed the company's entire accounting department simply to spite his son[12, p. 322]. Ford had an almost pathological dislike of accountants, financiers, share speculators and bankers. He felt that finance had too great an influence in business, particularly in imposing a short-term, blinkered focus on current profits. The chasing of the "immediate dollar" inevitably "breaks up service"[4, p. 42] to yield short-term profits at the expense of longer-term interests in product and process development and customer relations.

Earlier Ford had experienced difficulties with control over companies in which he had been involved. His financial backers did not share his vision and wanted a return on their investment – as Ford[4, p. 36] says: "… the new company was not a vehicle for realizing my ideas but merely a money-making concern – that did not make much money". Ford's backers had some foundation for their actions – many had backed an earlier company with Ford and lost money, and Ford was thought to prolong unnecessarily the design and development phase. The company took Ford's design for a car and put it into production with a different engine, renamed itself "Cadillac" and prospered under new management. Ford continued to see financial considerations as distractions from the main objective of business – if a good product was made and fairly marketed then profits should naturally follow[4, p. 156].

Ford financed his operations with cash wherever possible and avoided borrowing[4, p. 164; 5, p. 231]. He also avoided raising capital through equity. This was largely due to his desire to have complete control over the company and its operations. The financial health of a business depends more on its operations than on its financial manoeuvres[4, pp. 176]. Companies that rely on borrowing are often simply covering up management problems. It is inevitable

for managers to borrow money if that is easier than rectifying the fundamental causes of their problems[4, pp. 40, 223]. Finance was important for a business but Ford thought that it distorted the proper focus of business from long-term growth and public service to short-term profiteering, that it was often misused in speculation and covering for poor planning and management, and that it gave those who supplied it an excessive and unhealthy influence.

In controlling his own company Ford had problems initially with investors that wanted a return on their capital. He soon bought them out, but investment remained a problem for Ford because he did not appreciate the concept of opportunity cost as a rationale for rewarding investors. If they could earn rewards elsewhere they should go and take them, but he did not consider that a rationale for demanding equal returns from his business: "I have never been able to understand on what theory the original investment of money can be charged against a business". An investor who desired a return became a dead weight on the business in Ford's view – money in itself did nothing and could expect no reward[5, p. 30]. These ideas were practised by Ford who controlled the dividends paid out by his company – these were kept low so that the business could grow and prosper[4, p. 160]. Ford thought that financiers in business suffered from a form of myopia that saw no further than the dollars and cents involved and failed to comprehend the real activities and needs that underlay them. This superficial approach would lead a business into many errors – most particularly a continuing attempt to extract profits from the business rather than reinvest them in product, process or market development that was essential to business survival and prosperity.

Ford also held a simplistic view of macro-economics, apparently believing that by paying high wages and charging low prices companies could thereby stimulate aggregate demand. The economies of scale Ford realized with the MTPS seemed to provide tangible proof. At the start of the depression Ford even increased wages as a signal of his confidence and as a conscious means for stimulating demand[12, p. 369]. This could not last though and Ford later had to cut wages too. Business exists to serve the customers and profits ought to be reinvested to lower prices, expand and better serve the public and employees[4, p. 162; 5, p. 233]. Ford believed that too many business people followed ideas that were detrimental to their own and the public's best interests. In many ways Ford pursued Utopian ideals: he wanted to provide good and improving products at fair and reducing prices, while expanding his business to employ more and more people at good and increasing wages. He achieved these aims in the short term. General Motors forced change on Ford before the longer-term contradictions of his ideals became manifest.

Pricing policies

Ford remarks on how the greed of business people generally, and financiers in particular, interferes with the delivery of service to the public. When he started automobiles were luxuries and many producers priced them accordingly and opposed any move to change the character of the product or

market. Ford conceived of a mass market for cars in which a suitable product at a low price would be a great success. Much of the difficulty Ford experienced in introducing the Model T came not from consumers, but from distributors and support services who continued to treat automobiles as luxuries with owners to be exploited mercilessly. Only by confronting these problems directly and expanding the market, did Ford lay the foundation for the company's later growth. At first, the market for automobiles formalized this high price-low volume approach through licensing arrangements based on the Selden Patent. George Selden had patented the idea of an automobile in 1879 and kept it in reserve until they had become practical. In 1899 Selden formed a syndicate that sought to enforce his patent against several manufacturers who then joined the syndicate rather than fight it. Ford opposed joining the association and paying royalties and; when he lost the first hearing of the case, stood alone against them at the appeal court, which found in his favour[12, pp. 132-6].

Ford had an unsophisticated notion of price elasticity of demand and seems to have believed that a lower price would always be more than made up for through increased sales volume and improved revenues. He would rather make a low profit on each unit because he would be able to sell far more automobiles, a high unit profit as preferred by his contemporaries was seen by Ford as myopic since price gouging and volume restrictions were a business person's self-inflicted worst enemies. Ford[4] considered what the market wanted and the price it would pay; this then provided the target for product design and manufacturing capabilities. Ford anticipated much of Japanese practice[17] by focusing first on what the customer wanted and what they would pay to get it. Having established this he then looked to determine ways in which the product could be made. This approach contrasted with the complacent approach of other manufacturers who would look at what they could produce at current costs and only then judge whether a market might exist. Manufacturers taking current costs as the only basis for pricing would inevitably lose market share and profits to those who would constantly look for improvements. Oddly enough, Ford's chief objection to the usual approach was macro-economic – the country would have fewer goods and produce them more expensively.

Ford[5] sold the Model T on the basis of its costs and was active in continuously reducing them. He also used cost as a basis for his own purchasing. Detailed knowledge of production costs allowed Ford to obtain the best prices from his suppliers, and he notes that this knowledge was used to help improve the supplier's own operations.

Social welfare and labour

Ford's assembly line became the archetype of a dehumanizing industrial experience[10]. Ford himself[4, 5] went to great lengths to defend his system and highlight its benefits. Ford recognized and tried to cope with the labour problems created by the mass production and the assembly line. Staff turnover was substantial in 1913; *before* the wide use of assembly lines it was 380 per cent per annum. Only 640 staff in a total workforce of 15,000 had been employed

for three years or more. In 1914 Ford adopted the $5 day and thus provided what was an extremely good level of wages to qualifying staff. This was, for the time, a quite progressive and adequate response. Ford[5] claimed to rely on relatively high wages for many years and wherever his operations were sited, as one means for ensuring peaceful labour relations.

The high wages and other anti-union actions allowed Ford to operate without unions until the late 1930s. Ford's MTPS thus used a more flexible workforce than that criticized by the JIT proponents – there were no demarcation problems or rigidities in staff assignments: "no man can be allowed to consider himself as belonging to a particular craft and therefore barred from doing any work outside his craft"[5, p. 138]. Ford also notes that staff who became bored or unhappy with a particular job could apply for transfers as a mechanism for countering the repetitive nature of the work.

The MTPS was designed so that staff would accommodate themselves to its operations; in Ford's words: "The work and the work alone controls us"[4, p. 93]. Evans[11] describes this as technical control in which the production system takes on the main line management tasks of defining what is to be done and when to do it. This represented an intensification of effort and a dehumanization of the system in which people became simple machine attendants. Ford remarks that few staff sought work in more responsible positions and that these positions were always open. Evans[11] notes that Ford used very few supervisors with just one foreman of any rank for every 58 line workers, a ratio he thinks impossible except under the rigid production system Ford used. Ford[5, p. 99] minimized the role of direct supervisors and replaced them with the system: "Real leadership is unobtrusive, and our aim is always to arrange the material and machinery to simplify the operations so that practically no orders are necessary". In this framework job design was an integral part of the system's design with close supervision and control becoming a mechanical, system function.

Ford[4, pp. 108-10] identified 7,882 different jobs in the MTPS and carefully analysed them. This analysis allowed Ford to employ blind and disabled people in substantial numbers, such meaningful and productive work being in his view far preferable to charity. Ford employed 9,563 "substandard" men in his operations and had pursued an equal opportunities policy since 1914. This was a positive attitude. It was, however, offset somewhat by his similar attitude towards employing criminals while in prison. Ford felt that everyone should have an opportunity to work and provide for themselves. Charity and prison could never adequately meet the needs of the people involved to the same extent that meaningful employment would.

One major difference between Ford's MTPS and JIT systems arises from a consideration of the workforces used. The Japanese workforce is homogeneous and well educated. The labour force Ford drew on was neither. It included large numbers of people who had moved to the city from rural poverty, and many recent immigrants to the USA who knew little English. The MTPS was designed so that largely unskilled and uneducated people could quickly and effectively produce great numbers of a relatively sophisticated product. It was

very tightly focused on simple, repetitive tasks. Ford's[4, p. 108] job analysis found that 43 per cent of the jobs required one day or less training and that another 36 per cent would need less than a week's training. Only 1 per cent required more than a year's training and these were the highly skilled tool makers, most of whom would have worked in various capacities previously. Arnold and Faurote[7] reproduce multi-lingual forms used by Ford in 1913. Communications with staff presented major difficulties, so much so that Ford ran schools to provide basic literacy and practical education. Co-operative team efforts commonly seen with JIT would have been impossible for many of Ford's staff, and those areas in which they appear largely involved management or specialist teams working to improve the system.

Experts and experimentation

The drive at Ford was to mechanize operations as the most effective method for increasing efficiency. One striking aspect of the developments at Ford was their reliance on experimentation as a means for developing alternatives, Ford mentions developments in terms that indicate an experimental approach: "We tried the experiment of ..."[4, p. 82] and "... before we started our experiments…"[4, p. 87]. These comments are significant for two reasons. First, they emphasize the *ad hoc* approach Ford[5, p. 62] describes as the "Edison trial and error method". There were no computer models or sophisticated analytical techniques to assess proposals; the only tests that could be used were intuition and application. Ford dealt with real systems under real conditions so that great care was required. The second point emphasized is the incremental nature of the changes involved – modest variations were possible. Mistakes could then be easily undone and risks avoided, and successes (like the assembly line) could gradually be introduced or phased in where useful. Ford's MTPS was not susceptible to major development failures simply because it never suffered major development, it was continually evolving in small ways. This development mirrors that of JIT systems in which many small and gradual improvements built up to yield a system significantly different from the original one. Ford fostered an improvement ethos in his company that sought to improve its operations constantly.

Ford had a pronounced dislike of experts and shunned them[4, p. 86]. Ford wanted to have things done, and the chief problem with experts resulted from their knowing that these things could not be done. Ford did not care about expert opinion or experience; if a problem arose Ford wanted it dealt with. Long efforts and even failure were acceptable to Ford while simply denying that something could be done was not.

Conclusions and summary

One of the more interesting aspects of this review has been the relative ignorance of Western manufacturing managers about Ford's early approach to manufacturing, the period in which he had his greatest impact on automotive design and manufacturing development. He had an integrated systems approach founded on a market strategy allied to a focused manufacturing

system that emphasized quality, efficient production and an avoidance of waste; within a paternalistic framework intended to make the best use of a generally low grade but highly varied workforce. The parallels between the JIT approach and Ford's Model T production system are striking. Henry Ford was one of the foremost proponents of JIT systems – the original Ford production system in its years of development and operation anticipated and resolved many of the concerns that Ohno addressed with his Toyota production system. The key difference between the two systems follows from Ford's strictly and purposefully limited product line. The environments that the two faced were immeasurably different but their approaches are more alike than is generally recognized. The MTPS was not a piecemeal effort: it was a well-founded and highly effective manufacturing system that integrated marketing concerns, product and process design, and with due consideration for the technological, logistical and labour capabilities that existed. The critical point of departure came in the mid-1930s when Ford abandoned its single product strategy and reduced the effectiveness of its manufacturing system without appreciating that compensatory measures were either necessary or possible. The key element in Ford's Model T production system changed while the rest remained static.

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