3 The history of production systems in the automotive industry

3.1 Introduction

1885 marked the birth of the automobile when, Benz, and at the same time Daimler, introduced the first petrol engine driven four wheel carriage, the "Velozipede". Since then, automotive manufacturers not only strove to perfect the automobile as a product, but also the processes and organisation needed to build it. Standardisation played a key role in this process. In the automotive industry, the standardisation of parts initiated the standardisation of processes and work.

Production systems and their evolution represent a specific example of the changing nature of the form and function of standardisation. This significance of standardisation within production system has been long acknowledged. Historically, the theoretical discussion about standardisation and work reaches back to the Hawthorn Studies. The result of these studies have stressed the importance of the human aspect of work, thus raising the debate about the role of actors on the shop floor within the highly-standardised systems of mass production and Taylorism: the US system of mass production dissolved the traditional skills system. With this introduction of Taylorist and Fordist work organisation, the form and function of standardisation changed from the focus on standardised, interchangeable parts, to technical process standards like the moving assembly line, standardised skills and pay (the introduction of Ford's $5 Day). Beyond the shop floor, Ford extended standards to regulate the social lives of his workers by introducing a set of living standards workers had to adhere to in order to qualify for the $5 Day. Because Fordist mass production led to a decline in the quality of the products, the focus of standardisation subsequently shifted to regulating quality. With the approach towards a continuous improvement of standards, Toyota integrated the quality responsibility as part of the job of the workers on the shop floor and combined it with the highly standardised Taylorist work organisation. Intended to do away with the moving assembly line as the heart of the traditional assembly process layout and to stress the importance of the human aspect of work, Volvo introduced a human-centred production system at Uddevalla. It represents part of the movement against the dominant role of standardisation and standardised operations in production systems, associated with Taylorism, Fordism and Toyotism. Thus, it deliberately rejects the standardisation of work and represents the furthest developed example of a humanocentric system.

Covering a period from the end of the craft production system to the introduction of standardised production systems today, in this chapter I will trace the changing forms and functions of standards within production systems in the automotive industry and to historically examine its underlying driving forces. Of particular importance will be the object, intention and effect of standardisation within production systems.

To do so, I shall follow the historical time line and first examine the role of standardisation in the production organisation of automotive manufacturers during the transition from craft production to the American system of manufacturing, through to Taylorism and Ford's system of mass production. Thereafter, the two very contrasting production systems of Toyota and Volvo Uddevalla are introduced.

Concluding this chapter, I will examine the current trend of introducing standardised production systems in the automotive industry and analyse where they derived from. In this context I shall assess to what extent the Toyota Production System (TPS) has evolved as dominant model within this process.

3.2 The end of craft production

The history of production systems begins with the introduction of standardised parts for arms heralding the end of the period of craft production in America. Although this event is mainly associated with Whitney, amongst scholars, the impact he had in this process has been reduced to his role of a promoter of standardisation (Woodbury 1960:235ff.). Instead, standardisation efforts of the so-called "armoury system" became synonymously known as the "American system" or the "American System of Manufactures" (Hounshell 1984:15), and are attributed to the work of Simeon North and later perfected by John Hall (Hounshell 1984:1,28,41).

North doubted that manual work alone could support the production of interchangeable parts. He thus decided to build special purpose milling machines. This shows that the foundations of craft production and the importance of the all-round skilled worker were no longer sufficient to ensure the standardisation demands posed on the arms producers. To produce standardised parts, the use of machines became inevitable. But how could this machinery ensure a high output of identical parts? The answer lies in one of the prime objects of standardisation, the use of a "rational jig, fixtures and gauging system" (Hounshell 1984:6). Tools and measuring devices were used to check if each produced part conformed to specifications. First introduced by North, these forerunners of today's sophisticated quality control tools were improved by John Hall and in 1827 he achieved the first production based on standardised, interchangeable rifle parts.

Soon after the success of implementing machinery to produce standardised arms parts, the concept of standardisation spread to the production of sewing machines, typewriters and bicycles. The American machine tool industry was responsible for bridging the inherent gap between the production of arms and the produdtion of consumer durables.

According to Rosenberg this "technological convergence" was primarily possible because machine tool manufacturers learned new metalworking techniques from their work for the arms industry and in turn could apply this know-how also to the production of durable goods (Rosenberg 1963:414ff also in Nelson 1975:5). In addition, a transfer of learning between industries occurred as seen in the example of Henry M. Leland who initially worked for an arms manufacturer, but then applied his know-how of standardisation methods to the tools and sewing sectors and eventually founded Cadillac and the Lincoln Motor Corporations (Hounshell 1984:5).

In practical terms though, the most significant standardisation object which could be applied to any production context was the jig, fixture and gauging system. According to Hounshell, Ford's production system was based on the armoury practices of the jig, fixture and gauging system. The standardisation of bodyshell parts made available by the transfer of sheet steel punch and press work was previously tested and perfected and had already been standard practice in the bicycles industry. The moving assembly line was adopted from standard production process techniques which were already well established in both the meatpackers and the flour milling industries (Biggs 1996:8ff.)[1]

In order to be applied in a range of production circumstances, standards had to be documented. Plans and drawings of parts in scale were produced and thus the standardisation in the American System resulted in the formalisation of parts' specifications. Whereas before, craftsmen used their inherent knowledge of the parts' shape and size, detailed drawings now documented the exact measurements, angles and other specifications of the part to be manufactured. This already shows that those directly concerned with the production of parts were no longer involved in the product design process itself, instead formally drawn up plans provided guidelines of the design of parts: a step towards reducing the skills and the influence of the craftsman on the shop floor already imbued with Taylorist principles.

However, the role of the skilled craftsman had not yet been fully eroded. According to Gartman, at the beginning of the twentieth century, although standardised tools, particularly the power tools with hand controls, made work easier (ibid.:28), "only skilled craftsmen of the highest skills could turn the heap of parts into a running machine" (ibid.:23). This reliance on craftsmen was evident in all production departments, particularly in the assembly and the patternmaking shop (ibid.:26), thus during the early automobile production period it was standard practice that "skilled workers were themselves largely in control of their own work" (ibid.:24).

If the owners relied on their craftsmen for immediate production decisions, their trust had to be founded on the skills level of the craftsmen and it was indeed the degree of skills, which enabled craftsmen to sustain this degree of control within the production process. According to Gartman "skills were not theoretical,

[1] For a detailed account on the origins of the industrial processes an impact of the meatpacking, milling and other major US industries, please refer to the comprehensive accounts of Biggs 1996.

not formulated into a precise body of written rules and laws" (Gartman 1986:29) However, it was acknowledged that these skills "were largely empirical, gained mainly through long apprenticeships training and experience in watching and doing work itself" (ibid.). As skilled workers retained their status as craftsmen, with the rising demand of automobiles, the automotive manufacturers also fought to get these skilled workers into their factories. This competition for skilled labour drove up wages and in turn allowed the craftsmen to chose the best paid job, as did Walter Chrysler, "I wasn't willing to stick around a shop to prove that I was good. If they did not appreciate me, if any supervisor dressed me down, I'd get my time, pack my bag, forward my tuba and head for the next shop town" (Chrysler 1937:68). It was therefore usual practice that the skills level determined the degree of mobility during these early days of automobile production. However, the relationship defined by the interdependency between the factory and the skilled workers vanished as consumer demand increased (Meyer III 1981:13ff). Taylorism was introduced in the factory to allow for higher and more efficient output thus proposing the division of labour and the fragmentation of skills previously performed by craftsmen (Gartman 1986:44). This marked the end of the system of craft production in the USA.

3.3 Taylorism and standardisation

The replaceability of parts allowed an increase in both, the volume and speed of production. Simultaneously, the consistency of product quality was ensured. Thus, "increases in speed of production and volumes of production, attended by lower prices, more uniform quality, and population growth, resulted in much larger productive units" (Skinner 1985:285). Also, an increase in plant size, facilitated through the exploitation of the economies of scale, "permitted more fully integrated facilities" (ibid.).

Having standardised machines, tools, measuring equipment and buildings, the next step in the historical standardisation process was to standardise work sequences and tasks within the production process.[2] This was the major aim of Taylorism: "to develop a science for each element of a man's work, which replaces the old rule-of-thumb method" (Ford 1911:15). It attempts to standardise work ranged from the fragmentation of skills, standard task performance, to time and motion studies. Its single goal being increased production efficiency. As a result, Taylorist standards became work standards which could be used to measure and control work and workers.

[2] In 1896, Horace Arnold in a series of articles for Engineering Magazine had proposed that standardised plant layouts affect the quality of work, thus proposing a standardised factory design Arnold, H., 1896:267.

3.3.1 Historical background

Taylor's *Principles of Scientific Management* are standards to define the relationship between worker and work. According to Thompson, these aimed "to correlate and systematise all the best of modern developments in factory administration, and to push development further in accordance with principles discovered" (Thompson 1975:4). Taylor himself considered the rules he offered an approach calling for a total revolution of attitude towards work, a "systematic philosophy of worker and work" (Drucker 1954:280), and a political framework (Waring 1995:12). Indeed, as Waring states, a period in which "new managerial capitalism emerged from a search for ways to co-ordinate operations and control workers", Taylorism represented "the outcome of technological evolution, adjustment to market forces, value choices, and political struggle" (ibid.:10).

Its intellectual undercurrents stem from Adam Smith's (1723- 1790) *The Wealth of Nations* (1776) and Charles Babbage (1772- 1871) *The Economy of Machinery and Manufacturers* (1833). From the former, Taylor deduced two ideas: first, the division of labour as being essentially positive yielding increased productivity (Smith 1776:5) and second, the necessity to match skills and job tasks (ibid.:16ff.). In other words, the primary objects of standardisation for Taylor were first the fragmentation of skills into their smallest components (division of labour), and second the separation between mental and physical work.

3.3.2 Forms and functions of standardisation in Taylorism

The core of Taylor's *Scientific Management* (1911), "is the organised study of work, the analysis of work into its simplest elements and the systematic improvement of the worker's performance of each of these elements" (Drucker 1954:280). Work content (what) and task performance (how) were standardised and therefore the principles of Taylor became known as "one best method" how to perform a job (Taylor 1911:9). According to Taylor, this idea "is directly antagonistic to the old idea that each workman can best regulate his own way of doing the work" (Taylor 1911:30). The complex set of skills a craftsman previously had to perform were fragmented into individual units, with each worker then merely performing one particular task in a manner which was considered to be the most effective and efficient way.

Introducing precise standards of how a task should be performed, Taylor's army of Industrial Engineers changed the work and job content within production. This led to highly repetitive standard tasks which workers had to perform (Jürgens, Malsch, Dohse 1989c:4), assuming that the less tasks a worker had to perform, the more familiar these tasks became for him and the better, in terms of speed and precision, he could perform them. The combination of one-best-way and the decrease in work content (or increase in job fragmentation) points to the importance of standards:

> "The very idea of establishing work standards – how much output a manufacturer could expect from a certain machine tool, a work process, or a series of processes if labor did a fair day's work – is the very heart of Taylorism in particular and systematic management in general" (Hounshell 1984:250).

But how could the standard of finding one best way to perform a task be determined? In order to find out the most efficient and effective task performance, Taylor employed methods borrowed from scientific observation, namely time and motion studies. Hence, time and motion, too, became objects of Taylor's attempts to standardise skill performance. According to Taylor:

> "Scientific management requires, first, a careful investigation of each of the many modifications of the same implement, developed under the rule of thumb; and second, after a time study has been made of the speed attainable with each of these implements, that the good points of several of them shall be united in a single standard implement" (Taylor 1911:62)

The combination of the deskilling process on the one hand, and the increased use of scientific methods to determine work content on the other had two consequences: first, tasks became fragmented and highly repetitive, allowing unskilled workers to perform them; second, standards determining work content and work processes were set and controlled by experts (Jürgens, Malsch, Dohse 1989c:4).

Taylorism led to the birth of a new profession, a new elite of experts, the Industrial Engineer responsible for performing time and motion studies[3] and who later in the 1920s became the protectors of the holy grail of taylorist-fordist control structures (Jürgens, Malsch, Dohse 1989c:138ff.). The work of the Industrial Engineers changed the way work was performed "as scientific managers could conduct experiments to find the one best way of working and allow rule by science to replace government by soldiering work gangs and whip-cracking foremen" (Waring 1995:11ff.).

Furthermore, once a one best way to perform a task had been found, it was the Industrial Engineer who recorded the details of times and movement sequences. The industrial engineer thus contributed to the formalisation of tasks in terms of rules or descriptions "written on a single instruction card, or sheet" (Taylor 1911:63) which had to be adhered to. In other words, a core function of standardisation in Taylorism was the formalisation of work standards and practices thus not only specifying what is to be done but also "how it is to be done and the exact time allowed for doing it" (ibid.:17).

To ensure the adherence of the new tasks, Taylor assumed that the key goals of workers and management were that "give the workman what he most wants – high wages – and the employer what he wants – a low labor cost – for his manufactures" (ibid.:1), Taylor based his theory on the standard assumption that workers were primarily driven by monetary prospects (Badham and Jürgens 1998:36). Parallel to introducing the "task idea" (Taylor 1911:62), Taylor proposed "when

[3] As general manager of the Manufacturing Investment Company (1890-93) which in turn led him to develop a new profession that of consulting engineer in management.

workmen are daily given a task which calls for a high rate of speed on their part, that they should also be insured the necessary high rate of pay whenever they are successful. This involves not only fixing for each man his daily task, but also paying him a large bonus, or premium, each time that he succeeds in doing his task in the given time" (ibid.:63). An approach which was later realised with the introduction of the $5 day at Ford.

A second strand of Taylor's objects of standardisation relates back to the historical influence of the Babbage principle, which, in economic terms, states the relation between skill level and production costs, thus suggesting that mundane tasks required unskilled and therefore cheaper workers (Braverman 1974:61). Developing this principle further, Taylor deduced that each man's individual abilities had to match the specific task:

> "The essential idea is the scientific selection and recruitment for the range of industrial jobs of those people whose capacities and aspirations match the job requirements." (Badham and Jürgens 1998:36).

Moreover, Taylor suggested that men were either born to work with their mind or their hands, and thus were predestined to perform the tasks of either management in the office or the workforce on the shop floor (Taylor 1911:3). Indeed, as the mundane physical work required less intellectual efforts, men performing such tasks were supposed to be of lower intellect. In Taylor's words:

> "Now one of the very first requirements for a man who is fit to handle pig iron as a regular occupation is that he shall be so stupid and phlegmatic that he more nearly resembles in his mental make-up the ox than any other type. The man who is mentally alert and intelligent, is for this very reason entirely unsuited to what would, for him, be the grinding monotony of work of this character." (Taylor 1911:28).

This belief in turn lead Taylor to focus on the principle of selecting only candidates with suitable prerequisites which were required for the job. In other words, Taylor's selection process matched man and task:

> "The selection of the men, then, does not involve finding some extraordinary individual, but merely picking out from among very ordinary men the few who are especially suited to this type of work. " (Taylor 1911:30).

However, the function of management was not merely limited to matching workers and tasks, but the single most important duty of management was to ensure the adherence to the scientific principles of work (ibid.:41). Thus the primary goal resulting from Taylor's attempts to standardise work was an increased level of control over work and workers:

> "It is only through enforced standardisation of methods, enforced adaptation of the best implements and working conditions, and enforced cooperation that this faster work can be assured. " (Taylor 1911:41)

As seen in the discussion of standardisation in the period preceding Taylorism, the mounting influence of technology on the production process and new responsibilities of work organisation demanded a co-ordination of man and machine within the production process: the factory replaced the workshop, a centralist organization replace a decentral one.

Taylor proposed that his principles, deeply rooted in a theoretical and scientific approach towards issues of work (ibid.:11) (therefore having the claim to universal acceptance and applicability), would allow managers to control work in the new factories. Part of their control function was their power to give incentives be it in form of "hope for rapid promotion or advancement; higher wages, higher piecework prices or of a premium or bonus…" (ibid.:14). This particular task and other "homogenised and standardised jobs helped to simplify the functions of management to the point that some managers came to believe they were scientists applying general principles to specific cases" (Waring 1995:11). Indeed, managers embraced Taylorism insofar as "his fundamental premises met their philosophical and technical needs and by mid-century had come to dominate managerial theory and practice" (ibid.:9). Thus Taylorism was considered a new framework regarding the functions of management (ibid.:51). As a consequence:

> "Work is scientifically designed and organized by management to introduce the maximum possible division of labour and standardisation of tasks, the minimization of work cycle time, industrial engineering standards, piece rate incentive schemes and direct supervision" (Badham and Jürgens 1998:36).

The resulting control over the production process, according to Taylor, ensured the smooth and efficient flow. A prerequisite Ford used to create his system of mass production.

3.4 Ford's mass production: the foundation of modern production systems

"The generalized practice of scientific management coincides with the scientific-technical revolution" (Braverman 1974:86) and it was Henry Ford's achievement to combine Taylorist principles with technological advancement. During the American system, standardisation had made its mark by facilitating the production of replaceable parts, jigs, fixtures and gauges. In 1900, Christopher Newton introduced the grinding machine which allowed further standardisation of parts particularly for the automotive industry (Gartman 1986:41). However, it was not until 1913, when Ford at his Highland Park plant had combined these measures and created the first formalised production system, the system of mass production (Hounshell 1984:230). Particularly the fact that Fordist principles of production were transferred throughout Ford plants shows that these were considered a standard production system:

"This system is carried out in every branch and manufacturing unit, not only in equipment but in shop methods. The conveyors used at the various branches and the chains used in their construction all are standard. All stock comes in standard sizes. Blue prints are made in a certain standard form with the various information always listed in the same location on the sheet, so that no time need be wasted in hunting for it." (Ford 1926:87).

In the following I shall examine the form and function of standardisation in Ford's system of mass production: first focusing on the product and processes, in the latter part examining standards which regulated processes beyond the shop floor.

3.4.1 Standards in mass production

The key driver of Fordist standardisation measures was that there was only one standard product available (the model T) (Gartman 1986:43). This facilitated the use of standardised parts and hence enabled the mass production of cars (Hounshell 1984:218):

"Therefore in 1909, I announced one morning without any previous warning, that in the future we were going to build only one model, that the model was going to be 'Model T', and that the chassis would be exactly the same for all cars, and I remarked: 'Any customer can have a car painted any colour that he wants, so long as it is black.' I cannot say that anyone agrees with me." (Quotations from Henry Ford, McNair 1978:73).

The success and popularity of the model T were attributed to its low price, which in a period of sixteen years had more than decreased by half, from $850 in 1908 to $260 in 1924 (Biggs 1996:101). Ford made the car affordable for everyone. According to Gartman, "the low-priced cars of Ford and Olds generated the consumer demand that fuelled the drive for changes in the labor process" (Gartman 1986:40). At the same time though, these low prices created the foundation of the virtuous cycle of the US-American production model of mass production "linking process layout principles with labour market requirements, and division of labour" (Jürgens 2000:7). The five core elements which drive the virtuous cycle are:

1. A process orientation based on the principles of mass production
2. Job design is centred on highly fragmented tasks and little responsibility of direct workers.
3. Improvement and process innovation rested firmly in the hands of experts (Industrial Engineers)
4. Human resource management based on hire-and-fire strategy and skill acquisiting through on-the-job training
5. Labour relations marked by "distrust and antagonism" with management strongly defening its "right to manage" (ibid.:9).

The key driving force initiating this virtuous cycle was the fact that technological advancement had led to the creation of specialist machines able to produce identical parts, at a standard rate and in great numbers, and hence the focus of standardisation had become the production flow and handling of materials (Biggs 1996:108).

Particularly in areas where "the power of workers had already been reduced by standardisation, the division of labor, and mechanization", the standardisation of the production process was successful (Gartman 1986:100).

At the core of this process organisation was the development and installation of the moving assembly line, first to be introduced in Spring 1913 at Ford's Highland Park plant. The moving assembly line allowed for a continuous work flow system in which, during the assembly, each station was manned by a worker placing standardised parts in a standardised manner onto the moving standardised chassis.[4]

> "Along about April 1, 1913, we first tried the experiment of an assembly line...I believe that this was the first moving line ever installed. The idea came in a general way from the overhead trolley that the Chicago packers used in dressing beef. " (Quotations from Henry Ford, McNair 1978:91).

Ford's idea was not a novelty. As early as 1790, Oliver Evans applying the principle of process flow, had already recognised that "the movement of materials (grain in Evan's case) through the mill or factory is one of the most important ways to control the speed of production" (Biggs 1996:9). The process flow thus allowed grain "loaded at one end of the building to proceed through the stones and funnels of the mill to a vessel tied alongside it – supposedly without the need of interior workmen" (ibid.:11). This early example of a product and handling flow process was perfected by the meatpacking industry. As early as 1850, Evans' moving line had been installed in slaughter houses thus "eliminating the slow and cumbersome human handling of carcasses" (ibid.:27) and developments "in plant design meatpacking once again foreshadowed mass production in the automotive industry" (ibid.:29).

However it was Olds who first introduced the principle of the moving material handling process into the automotive industry in 1901. As Ford regularly visited Olds' plant, he transferred the principle to his production site at Highland Park (Gartman 1986:87).

The development towards the moving assembly line at Ford was divided into three phases. As early as 1906, Ford had experimented with work slides at the Bellevue plant (ibid.:84). In 1913, the power driven conveyance belt was installed in the flywheel magneto operation at Ford's Highland Park plant (ibid.:86) and the "monumental event" of the introduction of the moving assembly line in the final assembly took place in August 1913 (ibid..43).

Ford's aim of using a moveable assembly line was to reduce the amount of travel workers had to undertake to get from one work station to the next:

[4] For illustrations on these please turn to Hounshell 1984:226.

"If the workers were going to work like machines, Ford engineers concluded that the entire factory had to work like a machine, that the success of assembly line production depended on efficient supply of materials and parts to work stations" (Biggs 1995:53).

According to Gartman, "in an attempt to wrest the control of work flow away from workers, auto manufacturers began to transfer the handling of materials from human hands to mechanical devices" (Gartman 1986:83). An historical account from the Ford archives records this increased control over the process flow in a formal standard stating that:

"Arrange so that work will come to each man so that he shall not have to take more than one step either way, either to secure his work or release it; Keep the line moving as fast as possible." (quoted in Biggs 1996:107)

Thus this type of "progressive production" facilitated the constant flow of materials through the Highland Park factory (Meyer III 1981:31) and already three years after had become standard practice of all US automotive manufacturers. It also shows how Taylor's standard method of one-best-way were combined with Ford's standardised production flow, as seen in the following description of the sequence of assembly:

- "Place the tools and the men in sequence of the operation so that each component part shall travel the least possible distance while in the process of finishing.
- Use work slides or some other form of carrier so that when a workman completes his operation, he drops the part always in the same place – which place must always be the most convenient place to his hand – and if possible have gravity carry the part to the next workman for his operation.
- Use sliding assembly lines by which the parts to be assembled are delivered at convenient distances. " (Quotations from Henry Ford, McNair 1978:92).

Although Ford himself and later Hounshell disclaimed the direct influence of Taylor on Ford (Hounshell 1984:231ff.), stating that Fordism focused on mechanisation (machine replaces man) whereas Taylorism focused on the scientific study of one-best-way to perform a job, Fordism was marked by Taylor's methods of scientific management (Gartman 1986:50ff.). According to Jürgens, Malsch and Dohse, the assembly work conducted on the moving assembly line was the centre of the traditional taylorist-fordist control mechanism; taylorist insofar that strictly defined work methods and time limits were set, fordist, insofar that the speed and rhythm of work was determined by the moving assembly line (Jürgens, Malsch, Dohse 1989c:178).

With the help of Taylorist principles, Ford fragmented tasks further thus being able to standardise output of both machines and labour:

"The very idea of establishing work standards – how much output a manufacturer could expect from a certain machine tool, a work process, or a series of processes if labour did a fair day's work – is the very heart of Taylorism in particular and systematic management in general" (Hounshell 1984:230).

Hounshell's remark points at two issues. First, with the help of Taylorism, Ford intensified the standardisation of work content and job fragmentation, thus not only parts were interchangeable, but labour had become replaceable, too. In the words of Jürgens, Malsch and Dohse, workers were "merely an appendage of the production apparatus" (Jürgens, Malsch, Dohse 1989c:124), so that, "there was a strong element of repressive control embodied in the introduction of interchangeability and standardisation into the automotive labour process" (Gartman 1986:43).

Second, Hounshell's comment points at Ford's attempt to standardise Taylor's "fair day's work". As will be discussed in due course, the $5 day became the standard measure of the value of a fair day's work.

Let's turn to the issue of Ford's focus on the further fragmentation of tasks, first.

From the perspective of Nonaka and Takeuchi the impact of Taylorism at Ford replaced the previously un-written tacit understanding within production by a more complex system of clearly defining specific tasks as standards (Nonaka and Takeuchi 1995:64ff.). In other words, standardisation of tasks came with the introduction of Taylor's principles of scientific management (ibid.:37). Instead of having no guidelines, by spelling out how to perform certain tasks, standardisation was to limit the possibilities of how tasks were performed and therefore aimed at decreasing the overall complexity within production. By segmenting tasks into smaller units job contents were reduced and could be more controlled. Gartman cites an example from the assembly of engines, where one complete job had been divided into "eighty-four fragments, each meticulously timed down to the second and laid out progressively in a line" (Gartman 1986:47). On the one hand, this allowed higher quantities to be produced more efficiently (previously the motor assembly took 9.9 hours whereas the division of this job resulted in an assembly time of 3.8 hours – a 60 percent cut) (ibid.). On the other, the reduced job contents also lead to a subsequent shortening of cycles. Craftsmen were no longer challenged to perform complex tasks but were degraded to performing shorter and increasingly repetitive tasks:

"A worker must turn a lever the whole time in order to grind out machine parts. The perpetual, regular turning motion becomes a habit for him; he performs 30 or more turns to the right and left per minute for hours on end" (Nonaka and Takeuchi 1995:39).

This also led to greater control of management over the production process and the work of both skilled and unskilled workers (Braverman 1974:101). This degree of control is evident when considering the historical account recording the formalisation of work standards:

"Keep the work at the least waist high, so a man doesn't have to stoop over; Make the job simple, break it up into one, two, or at the most three operations" (Biggs 1996:107).

Moreover, as supervisors previously had dictated the pace, the introduction of the moving assembly line resulted in a shift from human control to mechanical speed control and foremen confirmed that "the line does a lot of your work for you. The men have to keep up with it. If I stand down at the end of my section, I can see if anything has gone wrong by one of the men, and I can find out why" (Walker, Guest, Turner 1956:13). The control function of the supervisor resulted in a shift from direct control of speed to indirect supervisory and visual control. This shift also underscored the importance of Taylor's creed of the division of labour and management, which contributed to Fordism (Braverman 1974:101).

From a human-relations approach perspective, Jürgens, Malsch and Dohse claim that this increased division between manual and mental work contributed to the curbed degree of influence workers could exercise in the production process, insofar as workers "who are most familiar with the technology and work organisation" (Dohse, Jürgens, Malsch 1985:124) were no longer tapped for their innovative ideas but instead were reduced to performing highly repetitive tasks. Standards were therefore considered as means to control the adherence of these new rules of work. According to Ford, "we expect the men to do what they are told. The organization is so highly specialized and one part is so dependent upon another that we could not for a moment consider allowing men to have their own way. Without the most rigid discipline we would have the utmost confusion" (Quotations from Henry Ford in McNair 1978:82).

This discipline was assured as the managers at Ford posted the production output of each man on a production board at the end of each row and according to Porter, the figures were "posted hourly, and the records of those who equal or better the quota set are written down in colored crayon" (Porter 1917:639). This standard measure was taken to stir up "competition among workers, who performed the same operation" (Meyer III 1981:62).

But what were the implications of Fordist standardisation?

Critical voices historically documented in films such as Chaplin's *Modern Times*, Lang's *Metropolis* (Ford 1989:7), books such as Huxley's *Brave New World* (Benyon 1973:17), Orwell's *1984* and the works of Braverman (*Labour and Monopoly Capital*) warned of the dangers of standardisation, "implying that man, too, could be mechanized" (Hounshell 1984:11).

Goldthorp et al. (1972) and critics pointing out the dangers of capitalist societies (Badham, 1986; Clegg, 1990; Thompson and McHugh, 1995), suggested that mass production resulted in "alienating the character of industrial work" (Badham and Jürgens 1998:37). According to Badham and Jürgens in their publication *Images of Good Work*, placed in a working environment which does not allow a sense of self-expression, creativity and identification with the work itself, the worker feels like an alien within the system and, underscored by the stress on money as sole motivator, is but a "self-serving cog in an industrial machine" (ibid.:36). Lewchuk argues in a similar vein:

> "But converting time into effort became more difficult as work became increasingly unskilled, repetitive, and monotonous and as workers, especially male workers, became alienated from their task. For men, this alienation was partially the result of the growing gap be-

tween the nature of work under mass production and the gender norms of skilled men who, building on their and their fathers' experiences in craft shops, associated independence and decision-making power at work with masculinity. " (Lewchuk 1993:825)

The results of both the alienation of the workers in production and the sheer physical strain of the repetitive work resulted in dramatic increase of labour fluctuations. In 1913 the total Ford workforce at the Highland Park plant consisted of 13.667 workmen. In the same year the daily absences in the Highland Park plant amounted to 10 percent of the total workforce and in the same year the rate of labour turnover reached a staggering 370 percent (Meyer III 1981:80). According to Meyer III, these high levels were "individual and semiconscious reactions" against Ford's production system reflecting the "dissatisfaction with changes in the conditions of work and the character of the workplace" (ibid.).

As production had become dominated by a standard product, standard parts, processes and job contents, Ford attempted to extend standards beyond the immediate objects of production to the welfare of the workers. Thus Fordism encompassed the standardisation of the immediate working environment in the factory and the habitation of the workers. Regarding the effect of the latter, Ford's goal of setting living standards for his workers resulted in two further objects of standardisation: on the one hand, with the help of the Five Dollar Day (profit-sharing plans) and the establishment of a job classification scheme, Ford attempted to offer a standard solution "to transform the attitudes and behavior of Ford workers" (ibid.:123); on the other, concentrated in the work of the Sociological Department, Ford's welfare programme attempted to standardise "social and cultural values for men to fit the regime of the mechanized plant" (ibid.). However, neither the monetary nor the socio-cultural standards of Fordism can be considered as independently functioning units, as the following section will show.

3.4.2 Standardisation beyond the shop floor

Despite a limited welfare programme set up before 1913, an investigation into the workers attitude towards work conducted by Lee, showed that long hours, low wages, undesirable shop conditions and arbitrary and capricious foremen mirrored their concerns about their new work tasks and routines in a mechanized plant (Ford Motor Company Archives 1913). The survey resulted in two measures aiming for one to introduce a job classification system (standardised job content ranking) and an increase of wages to a standard level of 5$ a day.

The first measure aimed at offering the workers a career ladder, giving them a chance of "social mobility within the factory" (Meyer III 1981:102). In detail, the system divided workers into six ranked groups ranging from mechanics and subforemen, skilled operators, operators, helpers, labourers, to special workers (women and children).[5]

Ford believed that the workers' living conditions, status and family backgrounds shaped their attitude towards work (ibid.:104). He therefore considered two options necessary: first, to investigate if workers lived up to the stringent Fordist standards of living and second, by increasing their wages to a standard $5 day rate, a common standard of living for Ford workers would be achieved. In January 1914, the company then announced a reduction in working hours (from 9 to 8 hours) and an increase in pay from $2.50 to $5.00 per day. At first sight, the general wage level of Ford workers suddenly rocketed above the usual wages within the automotive industry at the time. However, at a second glance, the system proofed to be based on a "profit sharing feature", which did not automatically raise all workers to this high wage level.

Only those workers conforming to a range of working, living and ethical standards set out by Ford, were eligible to receive the pay rise (ibid.:115). The investigation into whether workers qualified for the profit sharing pay rise, were administered by the Sociological Department which in 1916 had set out "the requirements by which the Company regards a man as eligible to receive profits" (ibid.).

The company requested each worker to give detailed accounts for this "sociological investigation". Equipped with checklists the department's investigators[6] set out to interview the worker, his family, neighbours; they inspected the workers' houses and living conditions:

> "The Record of Investigation examined three distinct aspects of the lives of Ford workers. First, it recorded a wide range of social and biographical information of each worker. Second, it gathered information on the economic and financial condition of the worker and his family. And, third, it explored the worker's morality, his habits and his life-style" (Meyer III 1981:130).

Through these investigation or (in today's terminology) social audits, "the truth about the men was scrutinized" (ibid.). This shows that standardisation during Fordism had been expanded to the social background of the worker thus pushing control through company standards beyond one best way to perform a job, to one best way to live. Standardisation had reached the private realm of the worker. This is also evident in Ford's account of the purpose of the Sociological Department. According to Ford explaining to the Industrial Relations Commission the purpose of this department was to:

> "explain opportunity, teach American ways and customs, English language, duties of citizenship…counsel and help unsophisticated employees to obtain and maintain comfortable, congenial and sanitary living conditions, and … exercise the necessary vigilance to

[5] For a detailed account of the evolution towards Ford's job classification system refer to Meyer III, 1981: Chapter 5.

[6] Similar to the role of quality inspectors discussed above, in this case social inspect tors/auditors.

prevent, as far as possible, human frailty from falling into habits or practices detrimental to substantial progress in life. The whole effort of this corps is to point men to life and to make them discontented with mere living" (Meyer III 1981:126).

This statement reflects Fords aspiration to extend the principles of his production system beyond the shop floor, envisaging Fordism as socio-cultural programme determining, structuring and standardising the life of his workers. According to Meyer III, "the Ford program sought to remake and to restructure working-class culture on sound middle-class, industrial values" (ibid.)

Critics, particularly those supporting a Marxist view of labour, strongly warned of the dangers that:

"In this microcosm, there is an illustration of the rule that the working class is progressively subjected to the capitalist mode of production, and to the successive forms which it takes, only as the capitalist mode of production conquers and destroys all other forms of the organisation of labour, and with them, all alternatives for the working population" (Braverman 1974:103).

According to this view, the $5 day was a measure which, in Braverman's terms could be described as bribe or coercion as it rewarded those workers who endured the working conditions (ibid.). Summarising this Marxist view, Gartman states that:

"The natural rhythms of the human body and mind – work and rest, alimentation and elimination – were subordinated to the mechanical rhythms of the line controlled by capital" (Gartman 1986:98).

And yet, Fords paternalistic vision marked a progress from the formerly prevailing view of "individual and moral causes of poverty" towards the explanation of poverty in terms of social and environmental factors (Meyer III 1981:123).

This was not only a vision, but in fact, resulted in a stabilisation of fluctuation in the labour turnover. Whereas "in 1913 the rate was rate was a phenomenal 370 percent. It fell to about 54 percent in 1914 and dropped to a low of about 16 percent in 1915" (ibid.:162) This decrease was also evident regarding the absenteeism rate (ibid.).

Through the introduction of extensive standardisation measures, the labour turnover was reduced and the goal of exploiting the economies of scale was reached. With the increase in production output, the average unit cost decreased, leading to economies of scale. In the case of Ford, both internal and external economies of scale were the goals of standardisation.

Ford's intensive deployment of expensive machinery led to technical economies of scale. Moreover, following Taylor's principle of the division of work between management and production work, through "unfettered management" (Jürgens 2000:8), Ford profited from the managerial economies of scale. In addition, as production tasks required less skills, Ford's personnel expenses decreased, as unskilled workers were paid lower wages and, as discussed above, the Five Dollar Day, was an monetary incentive for selected workers only; a control tool disguised as a monetary incentive as a control tool gradually waned in the aftermath of the postwar period, the recession of 1920-21 and the rise of industrial unionism during the thirties (Meyer III 1981:199ff.)

Looking at the external economies of scale available during Ford's mass production period, being located in Detroit, the industrial centre of the automotive industry, the company could draw on a sufficiently large local workforce. At the turn of the century the Detroit area consisted mainly of mechanics, specialists and labourers as surveyed in 1891 by the Michigan Bureau of Labor Statistics. This professional base provided the source of Fords early production (Meyer III 1981:46). However, with the influx of immigrants into Detroit, the level of skilled metal workers decreased and this "massive influx of immigrant workers presented Ford officials and managers with their most formidable labor problem (ibid.:75). Immigrants primarily were peasants from Southern and Eastern Europe "without industrial work-skills and work-habits" (ibid.).

Thus, Taylorist principles of offering "narrrow skill/low responsibility jobs" allowed for the employment of these unskilled workers and resulted in the exploitation of external labour economies.[7] The labor problem was hence solved, as "with a minimal amount of training, an immigrant or farm migrant could perform one fragment of the previously skilled labor process efficiently" (Gartman 1986:53). This led to "the reduction of unit labor costs through reducing the labor time expended in the production of an automobile" (ibid.:89).

Although the Five Dollar Day and Ford's welfare system served as powerful economic incentive for these workers, World War I resulted in some fundamental changes which gradually began to undermine Ford's system of mass production. For one, "paternalism gave way for more authoritarian patterns as a means to insure social conformity" (Meyer III 1981: 196), culminating in the rise of the Auto Workers' Union. As long as Ford continued to pay high wages, workers "took the money and ran along with it" (ibid.: 197). The change occurred gradually starting with the recession of 1920-21, and when after the General Motors strike at Flint, Michigan, in 1936-37, industrial unionism had become institutionalised in the automobile plants. According to a flint striker "the inhumane high speed is no more. We have a voice, and have slowed up the speed of the line. And we are now treated as human beings, and not as part of the machinery. The high pressure is taken off...it proves clearly that united we stand, divided or alone we fall" (ibid.: 200).

Particular standards concerning working hours and working conditions, had been always fought for by the unions. This applies also for the American automotive union, the United Automotive Worker Union (UAW). After their foundation in the 1930s, the UAW fought against breaking standards in order to protect workers from speed ups of the assembly line. Unionism at Ford became institutionalised in the 1941 contract and subsequently the UAW Ford Department in negotiation with the Ford management influence a number of standards ranging from "pension plan, health care benefits, workplace health and safety protection, skilled

[7] For an extensive discussion on the effects of Taylorism and Fordism on the surplus value and surplus labour see Braverman 1974:175ff.

trades recognition, a shortened work week, more paid days off, supplemental unemployment benefits, and a guaranteed annual income credit a number" (Walter P. Reuther Library of Labor and Urban Affairs, 2003).

In Germany, through their collaboration with the REFA, union representatives attempted to shape standardisation processes at a very early stage, and to influence methods and the qualification of Industrial Engineers.

Summarising this part, mass production represents the first production system because it integrates standards which until then had not been combined into one system of production organisation. The key components of the system of mass production are: technical and process standards, work standards and social standards. Ford deployed and refined the system of jigs and gauges and not only introduced new technical standards of car parts (such as wheels) but also entire components, such as transmissions. Moreover, by developing the moving assembly line, Ford extended standardisation to production processes which thus determined the work places and work content. The rhythm of the line determined the speed and rhythm of work. Ford deployed Taylor's *Principles of Scientific Management* to regulate the sequence and timing of tasks.

The third component of Ford's system of mass production is the extension of standards from the shop floor to the social sphere of the workers. The 5$ day is an example of how Ford used the monetary incentive to get workers to adapt his social ethics. Due to the labour surplus, if workers opted to work for Ford, they had to conform to Ford's social vision and to accept and adapt to the living standards he envisaged as the American way of life. Ford's system of mass production did then not only erode the control of workers over their work, but also penetrated into the workers' private spheres, affecting their control over their private, social and cultural areas of life. It is now interesting to see how the system of mass production evolved in the decades after Ford and how the form and function of standardisation changed within this evolution. To examine this, the following part considers the role of standardisation in the Toyota Production System (TPS).

3.5 The Toyota Production System (TPS)

Whereas Ford's system of mass production evolved during a period of economic growth, the Toyota Production System (TPS) proposes another system of standards to achieve maximum economic efficiency with a minimum of available resources. Thus a key focus of the TPS is to reduce any kind of wasteful, non product-value adding activity. The core approach how to achieve this is the system of continuous improvement. Standards are subjected to the constant refinement and improvement. This concept is at the core of the TPS and also points out the difference to the system of mass production. For whereas Ford used Industrial Engineers to set fixed standards of work, at Toyota, the standard setting, and above all, the constant refinement of standards is a major responsibility of the workers on the shop floor. To examine the role and regulatory function of standards in the Toyota Production System, I shall now consider its evolution in detail.

3.5.1 Historical background

In the early decades of the twentieth century, market conditions in Japan mirrored those of Germany, as "customers were mostly limited to a small number of wealthy upper-class people with curiosity" (Fujimoto 1999:28). Local automotive production was "extremely small" not exceeding a cumulative output of "several hundred units" (ibid.34). The production of automobiles in Japan first gained significant momentum when in 1925 Ford, as the first US-automaker, set up a wholly owned subsidiary to build its knock-down plant at Yokohama introducing moving assembly lines for both chassis and body. GM followed Ford's example and also set up its knock-down assembly subsidiary in Osaka in 1927. On a smaller production scale and instead of making a foreign investment in Japan, other American automotive manufacturers, amongst them Chrysler, opted to import their parts to Japan, and deployed Japanese companies for the assembly.

Despite this US-dominance within the Japanese automotive market, during the early 1930s, the automotive branch of the Toyoda Automatic Loom Works Ltd, (later to be renamed Toyota Motor Co. Ltd.), led by Kiichiro Toyoda, commenced its research for automotive engines.[8] After having started building a pilot plant in Kariya in 1934, and aided by the introduction of machine tooling equipment from Germany and the US, the first Toyota prototype engine was finished by autumn 1934. Parallel to the development of this engine, dissembling Chrylser and Chevrolet cars, and copying genuine parts of Ford and other American manufacturers, Toyota developed prototypes for its own car bodies, chassis and gear parts (ibid.:36). In addition to this hardware, Kiichiro encouraged his staff to conduct tours of US-automotive manufacturers at their home locations in order to learn about the system of mass-production at first hand.[9] These efforts culminated in the introduction of the first Toyota prototype of the A1 model, a "five-passenger sedan with a 3400c engine" in May 1935 (Fujimoto 1999:36). According to Fujimoto, these early attempts at building local Japanese cars at Toyota were "more or less imitation and a patchwork of American automobile technology" (ibid.). With a local market share of Japanese automotive manufacturers amounting to merely 3% Toyota's early efforts in 1934 remained insignificant (ibid.:34).

In the same year, assembly output of all US-knock-down plants peaked at 92% of the total Japanese domestic demand (ibid.:36). This market dominance motivated Ford to plan a second, new and much enlarged plant, thus continuing its strategy to expand its global operations. This aided the transfer of the Ford production system beyond the USA, an approach also evident in Ford's expansion strategy in the UK, as discussed by Tolliday (1998) and Lewchuk (1992). The influence of the US-manufacturers was also evident as they dominated the production of trucks with a total of 92% of total Japanese domestic demand being either

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[8] Upon learning about the proposed sector regulation by the government, in course Toyota switched from its focus on automobiles to the production of trucks.

[9] These initiatives pre-shadowed the extensive tour of Ford plants by Eiji Toyoda and Shoichi Saito after the labour crisis two decades later.

assembled or imported by US-manufacturers (Fujimoto 1999:34). However, this dominance was soon at an end as the Japanese government, driven to ensure adequate supply for military vehicles, introduced the Automobile Manufacturing Enterprise Law in 1936. This legislative act affected the Japanese domestic automotive manufacturers in two ways. First, it "prevented the operation of foreign automakers in Japan, and subsequently led to a shut down of the US automobile assembly by the end of the 1930s" (ibid.). Second, the act subsidised three domestic truck manufacturers, Toyota (Toyota Motor Co. Ltd. Founded in 1937), Nissan (renamed Nissan Motor Co. Ltd. After being founded through a merger in 1933) and Isuzu (initially founded as Tokyo Jodosha Kogyosho and in 1949 renamed Isuzu Motors Ltd.). "Filling the gap created by the US makers' exit" (ibid.), the Kariya plant, completed in 1936, produced 150 units per month, a rather modest figure compared to the large scale production of Ford's output of several thousand units per year (ibid.:36). In order to meet the growing domestic demand for cars, Kiichiro initiated the construction of a second, bigger Toyota plant at Koromo. Upon completion in 1938, it employed 5.000 staff and produced 2.000 units per month.

Influenced by the production concepts of the Ford knock-down plants and attempting to realise the economic benefits, standardised products, standardised and interchangeable parts, special purpose machines and the moving assembly line, Toyota introduced the American mass production system at Koromo. However, these concepts could not be transferred identically, rather "their adaptation had to be selective, taking the limits of the domestic market and existing production systems into account" (ibid.:35). Compared to other Japanese automotive manufacturers, for instance Nissan relying on "packages of product and process technologies", Cusumano suggests that Toyota selectively integrated American technologies into its already existing system (Cusumano 1985:62). The intention was to use local know how and creativity to develop a production system that would suit the particular Japanese cultural and economic context (Kiichiro quoted in Ohno 1993:119). Despite attempts at this selective integration, the production operations at Toyota were still predominantly based on craft-type production principles, as a former Toyota worker noted:

> "Many elements of craft production persisted, and craft skills were required in job shop environments. Workers machined a variety of parts, while sharpening their own cutting tools. Process flows were often disturbed, work-in-process inventories piled up, and lack of balance in machine utilization occurred" (Toyota Motor Corporation Ltd. 1978:95).

Fujimoto suggests that the reliance of craft-type production principles continued up to the 1940s, and "despite the strong influence of the Ford system (also Taylorism), the flexible nature of the early indigenous (craft-type) systems of those days carried over to the early Toyota Production System" (Fujimoto 1999:37).

In the aftermath of World War II, with limited financial resources, Toyota was forced to abandon any investments in the technological update of its production. According to Fujimoto, Toyota instead was forced to improve productivity from within. Combining elements of Taylorism (standardisation of work design) with company specific elements such as a particular production flow and machine layout, multitasking (*takotei-mochi*), and levelling of production pace (*heijunka*), according to Fujimoto these measures "deemphasized the existing craft-type system" (ibid.:39). The results of these measures were twofold. First, traditionally crafts-type production was eroded leading to conflict between craftsmen and foremen on the shop floor. Second, the new measures had increased productivity - even as far as reaching overproduction in the face of recession, thus leading to a potential bankruptcy of Toyota (Japan Management Association 1985:preface). This situation forced the company to fire a substantial percentage of its workforce. Together with the increasingly standardised production methods and overproduction, this large-scale staff dismissal contributed to a labour crisis in 1950 culminating in long strike by Toyota workers (Fujimoto 1999:39).

The situation changed when during the Korean War, the American Army Procurement Agency (APA) issued substantial orders of motor vehicles. This helped to aid the recovery of the Japanese motor industry. In response, Toyota introduced several new truck models, and in 1955, the Crown RS-30 passenger car was launched. Unlike the other Japanese manufacturers, Toyota did not produce vehicles under license agreements with European manufacturers (as for instance Nissan or Isuzu did, see Nomura and Jürgens 1995:23); instead, the company relied on its own product development. According to Nomura and Jürgens, management was particularly concerned with developing own solutions in the development of production technology (ibid.:22). Parallel with the introduction of passenger cars, the company continued to deploy American management practices, shaped by the principles of scientific management. In addition, the issue of the control of quality (as discussed in the previous chapter) had been raised by Edward Deming's lectures of 1950 and 1951 in Japan and thus Toyota increasingly drew on the tools of statistical quality control (SQC), such as Shewhart control charts (Juran 1995:536ff.). First-line supervisors were trained in using these tools thus instilling the awareness on the shop-floor to continuously improve processes.

Toyota also strove to develop its own solutions within production, particularly in the case of adopting the tools of scientific management such as time and motion studies and the remuneration system. Coupled with the encouragement to continuously improve processes, this resulted in a distinct link between performance incentives and efficiency improvement which according to Nomura and Jürgens is one of the key determinants of the success of the company's production system, as will be discussed in detail below (Nomura and Jürgens 1995:23). In addition to the linkage between the continuous improvement process (CIP) and remuneration, by the late 1950s, a kanban system, controlling production and inventory levels was installed. However, these measures remained isolated attempts at improving production efficiency, and according to Fujimoto, "neither systematic approaches of technical assistance to the parts suppliers nor company-wide quality management had been effectively installed in the 1950s" (Fujimoto 1999:40).

The 1960s, the explosion of domestic customer demand for cars led to a "motorisation" mania (ibid.) and necessitating the set up of large-scale production facilities. The growth rate of the automotive industry in Japan during the 1960s averaged at 26.9% (Nomura and Jürgens 1995:28) and between 1960 and 1970, its production output rose from 500.000 units per annum to 5 million units (Fujimoto 1999:40). Moreover, the proliferation of consumer taste called for a shortening of product development times and the product life cycle of a car was reduced to four years (ibid.:42). As a result, the black box parts system integrating suppliers already during the early phases of the product development process was developed. The supplier integration into the product development process subsequently led to a divide within the automotive supplier segment into those suppliers with research and development capacities able to provide design and construction services (according to Asanuma (1984) so-called Type 1 suppliers) and those merely responsible for providing production parts and capacities.[10] Parallel to the supplier integration, during the early 1960s, Toyota introduced a company-wide total quality management system, winning the Deming price in 1965 and subsequently extending the total quality management concept (TQM) to its suppliers (Fujimoto 1999:42). Until then Toyota had not attempted to formalise its production system into a written format, but relied on a system of learning by experiencing. Suppliers were invited to witness and study how Toyota produced its cars. According to Ohno, this type of presentation allowed Toyota to demonstrate efficient production processes live, on the shop floor (Ohno 1993:61). This approach made it easier for suppliers to understand the actual running of the system on the shop floor (ibid.).

Whereas the 1960s were marked by a surge in domestic demand, for Toyota the 1970s were fuelled by a increase in international demand and hence the company intensified its export activities. The decade between 1970 and 1980 witnessed a growth of exports, particularly to North America, from 1 million to 6 million cars of Japanese manufacturers (Fujimoto 1999:43). Unlike other Japanese manufacturers, Toyota met challenges like safety problems, the effect of the oil crisis in the mid-1970s, an increasing environmental awareness calling for lower emission levels, and the expansion from a domestic to an increasingly global customer base. According to Fujimoto, the success of Toyota was due to three measures (ibid.). First, investments were made in technologies particularly for the improvement of its engines and in numerically controlled machines (ibid.:44). Second, the range of Toyota models was expanded to cater for the particular customer needs outside Japan (ibid.:43). Third, already installed elements characterising Toyota's production had to be refined "for a sharper focus on continuous improvement in productivity and quality" (ibid.:44). These improvements also affected Toyota's relations with its suppliers. According to Fujimoto, "both internal production management and supplier management were focused on improvements in manufacturing performance (quality, cost, delivery) " (ibid.). This transfer of standards "meant the establishment of tight operational ties between the assembler and suppliers, including kanban delivery...and elimination of receiving inspection for incoming parts" (ibid.:318). This process was facilitated as Toyota communicated its "routi-

[10] For a detailed discussion on the relationship between Japanese manufacturers and their suppliers, refer to Nomura and Jürgens 1995:chapter 2.2.

nised manufacturing and learning capability," (ibid.:17) thus synchronising the interfaces between manufacturer and supplier (Kenney and Florida 1988:137).

The success of Toyota's way to produce cars was soon recognised by the other Japanese manufacturers. According to Monden, by "introducing the Toyota production system partially or totally", other Japanese automotive manufacturers "conquered the depression of the oil shock" (Monden 1983:401). The spread of Toyota production principles to its suppliers pushed ahead the formalisation of the Toyota production system. A partial contributing factor in this process was a lecture series by the Japan Management Association intended to teach other Japanese manufacturers about the production approach of Toyota (Japanese Management Association 1985: preface). Including Taiichi Ohno's (then Toyota executive vice president) contributions, the first formalised attempt at a description of the Toyota Production system was first published in 1978 (ibid.). By 1985, it had achieved a rank among the top-selling books in Japan then already in its thirty-fifth printing edition. Particularly for small and medium-sized companies trying to survive in the aftermath of the oil crisis, this book "gave them new direction and encouragement" (ibid.). The Toyota Production system became synonymous with the best practice model of manufacturing for Japanese companies.

Expanding their export activities, the efficiency of the Japanese manufactures became internationally recognised during the 1980s. According to Mishina (1998), between 1975 and 1980 the export rate of Japanese cars to the US amounted to a steady 20% annual increase with the share of Japanese cars contributing to 21.4% of the US market by 1980 (Mishina 1998:101). In conjunction with a slump of 21% in the sales volume of US automakers between 1979 and 1980, a political debate about solutions for protecting the Big Three US automakers commenced. In 1981, pressured by Washington and the United Auto Workers Union (UAW), the Japanese government announced a Voluntary Restraint Agreement limiting the importation of Japanese cars on the basis of a set quota (ibid.). To avoid this quota, Japanese automotive manufacturers subsequently set up transplants foremost in North America but also in Europe.[11] In case of the US, by the mid 1980s around 200 Japanese automotive suppliers had followed suit (Fujimoto 1999:45).

From this point, the evolution of the Toyota Production System took three major paths: the evolution of the TPS in transplants and joint ventures outside Japan, in new Toyota plants set up during the 1990s in Japan, and at plants of joint venture partners of Toyota, particularly at world-wide GM plants.

[11] Honda started it operation in Ohio as early as 1979, Toyota instead decided to form a joint venture with GM and set up the New United Motor Manufacturing Company (NUMMI) in Fermont in 1984.

3.5.2 The evolution of the Toyota Production System in the 1980s and 1990s

The setting up of Toyota transplants outside Japan played a significant role in the evolution of the Toyota Production System: it contributed to the formalisation of the TPS and through joint-venture transplants introduced the company's production system to Western joint-venture partners.

Despite having attempted to issue an outline of the system for its suppliers in the 1970s, as Toyota set up plants outside Japan, "Toyota managers felt they had to reinterpret the existing Toyota system, clarify the logic behind it, translate it into English" (Fujimoto 1999:47). Moreover, Toyota's global expansion in North America during the 1980s also forced its management to consider the compatibility of its production methods with the Western production environment. They were also faced with what Abo termed the "Application-Adaption dilemma", namely the choice to "introduce superior elements of their management and production systems to the maximum extent possible (application)" or "to modify those same systems in an effort to adapt to various local environmental conditions (adaptation)" (Abo 1998:216).

Founded in 1983, NUMMI, the joint venture between GM and Toyota, was to "help Toyota learn about US suppliers and labour. For its part, General Motors wanted to learn about Japanese manufacturing systems" (Adler, Goldoftas, Levine 1989:129). According to Adler, NUMMI "made very few changes to the Toyota production system itself, " (ibid:128) pointing at a clean-sheet transfer strategy. For example, the core object of TPS standardisation, the standardised operations sheet was used at NUMMI. Copying the initial TPS approach, tasks workers performed at NUMMI "were analysed down to its constituent gestures, and the sequence of gestures was refined and optimized for maximum performance" (ibid.:132). Moreover, team leaders and individual workers were responsible for the continuous improvement of these standards.

However, regarding the issues of human resource management (particularly pay levels) and labour relations, local conditions necessitated an adaptation of TPS to US standards. Resulting from Abo's research on the degree of hybridisation, concerning labour unions, all Japanese companies setting up plants in the US, "were most anxious about union matters, fearing not only the militancy of Western unions but also their practice of organizing across company boundaries and bringing demarcation issues onto the shop floor" (Abo 1998:223). In order to appease the unions, at NUMMI, for example, the foundation of the co-operation between the unions and the management was enshrined by contract stating in its introduction that "we are committed to building and maintaining the most innovative and harmonious labour-management relationship in America" (Adler, Goldoftas, Levine 1998:136). Moreover, the unions gave up their right to strike over work standards and health and safety issues. In turn NUMMI management "was contractually obliged to consult the unions on matters ranging from the pace of work to major investments" (ibid.).

Achieving competitive quality and productivity results, the transfer of the TPS to NUMMI was considered as access particularly as "Toyota managed to transplant the bulk of its production system as well as much of its administrative structure and supplier relations to NUMMI" (ibid.:157). From a societal view, the success of NUMMI is explained in terms of its ability to adapt to the "American workforce, union, regulations, and culture" (ibid.:158). Yet NUMMI failed to "set a new global standard for performance" and Japanese companies continued to provide the bench mark with regard to their lead in the technical dimension (ibid.).

According to Boyer, the setting up of transplants thus proved an "opportunity to pick out the real and permanent roots of productivity and quality from factors that are contingent upon the Japanese context" (Boyer 1998:41). In addition, it was also necessary "to dispel some of the negative misunderstandings of the system" which had been building up for years (Fujimoto 1999:47). Thus Toyota's production methods were formalised into a printed systems description, titled *An Introduction to The Toyota Production System (1987)* and later *The Toyota Production System (1992)*. The formalisation of Toyota's production principles into what since then has become known as the Toyota Production System was driven by the company's global expansion through the setting up of American transplants.

Parallel to this formalisation process, the operations at the transplant of Japanese manufacturers and suppliers, including Toyota, became a major focus of academic research (Fujimoto 1999:45). Allowing for a direct comparison between Eastern and Western manufacturing practices, researchers attempted to analyse and explain the competitive advantage of the Japanese production methods, both at the transplants and in Japan itself. One contribution of particular interest during this research period was the publication of *From Fordism to Toyotism? The Social Organization of the Labour Process in the Japanese Automobile Industry* by Dohse, Jürgens and Malsch in 1985. Preshadowing the findings of the MIT study five years later, the authors came to the conclusion that Japanese manufacturers - foremost represented by Toyota - were "undoubtedly capable of mass producing qualitatively good automobiles with considerably less labour" (Dohse, Jürgens, Malsch 1985:118). Together with other research undertaken by Western academics or consultants, publications fuelled efforts by Western automotive companies to catch up with their Eastern rivals. The era of looking East (Nomura and Jürgens 1995:13), commenced in the 1980s, reaching its climax with the publication of the International Motor Vehicle Report issued by the MIT in 1990 (Womack, Jones, Roose 1990).

At a time when "due to shifting exchange rates, altered tax structures, and the emergence of Japanese competition in the upscale market" (Jürgens 1995a:293), Western automotive manufacturers were ever more faced with severe cuts in the essential sales of automobiles in the US market, the authors of the MIT study, hailed the Toyota Production System to be the universally acknowledged best-practice concept of the production and corporate organisation (Nomura and Jürgens 1995:14) representing a lean production solution for the dilemma the Western automakers were then faced with. A phase of "learning from Japan" (Jürgens 1993:3) commenced. Despite failing to account for the context of the TPS to the specific cultural, historical and social background of Japan (Nomura and Jürgens 1995:14ff.), through the MIT study, the TPS became the "Paradigma" (ibid.:14) within the lean production discussion; and as Dohse, Jürgens and Malsch in 1985 had already suggested, "Toyotism" became the suggested *Leitmotif* for the Japanese model of manufacturing .

At the same time as the MIT study promoted the TPS in the West, the overheating economic effect of the "bubble boom" experience during the second part of the 1980s, already dawned in Japan (Fujimoto 1999:47). At Toyota, the post-lean discussion had already begun aiming to adapt the TPS to the looming economic recession and changes in the Toyota's potential labour recruitment pool and the age of Toyota's workforce; a workforce primarily consisting of recruits of the baby-boom generation, now reaching the age around 40 (Nomura and Jürgens 1995:213). Thus two developments marking the post-lean period at Toyota can be distinguished: organisational changes and changes to the Toyota Production System. According to Nomura and Jürgens, the adaptations regarding the policies of work covered three aspects. First, Toyota flattened its hierarchy and career path by reorganising white collar work in the administrative and technical areas (ibid.:214). However, apart from easing the career path from Hancho to Kumicho[12] in 1987 (Nomura and Jürgens 1995:214), the overall hierarchy within production remained unchanged. Second, the remuneration system was reorganised, introducing an age and skill bonus, reducing the productivity bonus from 60% to 40%. Third, the remuneration structure changed and the assessment of staff potential played an increasingly dominant part in pay level differentiations (ibid.:221).

Regarding the challenges of the recession on the Toyota Production System, according to Kojima, TPS as a lean production system was improved further and developed into a system of "Super lean production" (Kojima 1995:197). During the late 1980s, Toyota had been experimenting with introducing aspects into the TPS aiming at "improving workers' morale while securing productivity" (Niimi and Matsudaira 1997:82). One way of achieving this was to change the production layout, particularly the assembly line structure. Underlying the new assembly line is the continuous improvement process (CIP). According to Niimi and Matsudaira, the assembly line "will continue to be improved and will continually evolve in response to changes in the social environment and the growth of workers in terms of skill and attitude towards Kaizen" (ibid.:83). A first adapted line was introduced at the Miyata plant of Toyota Kyushu in 1992. Three adaptations are noteworthy.[13]

First, the link between individual production lines consists of a buffer with sufficient space for four to five waiting vehicles so that differences in working pace can be buffered (Kojima 1995:32). According to Nomura and Jürgens, from the traditional perspective of lean production a classical case of waste in processes as no value is added to the vehicles moving between the mini-lines (Nomura and Jürgens 1995:232).

Second, during the bubble boom years of the 1980s, the automotive industry had acquired the so-called 3K image: Kitanai (dirty), Kitsui (stressful) and Kiken (dangerous) (ibid.:234). The potential surplus male labour pool had shrunk and

[12] Kumicho refers to the group leader or supervisor, whereas Hancho denotes team leader or foreman, see Nomura and Jürgens1995:111.

[13] For a detailed discussion refer to Kojima 1995.

fluctuation problems occurred (Shimizu 1995). For example, by the end of 1991, three quarters of the newly recruited workers in April 1991, had already resigned after having found better jobs in other sectors of the Japanese industry (Nomura and Jürgens 1995:234).

Third, whereas the production layout in other Toyota assembly plants had been centred around one long production line, at Kyushu, the line lay-out resembles more that of a fishbone structure with one central spine (main assembly line) and laterally extending bones ("mini-lines") (ibid.:232, see also Shimizu 1995).

In contrast to the traditional TPS, these buffers affect work in three ways. First, the psychological threat imposed by the pull chord is reduced as eventual stops only affect the mini-line but do not bring the entire line to a standstill. According to Nomura and Jürgens, the pressure on the individual to use the pull chord decreases and one of the key aspects of work pressure is thus being eliminated (ibid.:233). Second, the working processes within the mini-lines are structured to ideally provide holistic and related tasks (ibid.). Thus the group has received additional autonomy regarding the organisation of work and job rotation. Work in the sub-lines is organised by the teams: the management and control of the team remains the responsibility of the team itself (Kojima 1995:49).

The TPS also evolved along is through its adoption of joint-venture partners in the West, primarily throughout GM's international plants (notably in the USA at NUMMI in 1983, as pointed out above). After having learned the Japanese manufacturing techniques through its main joint ventures at NUMMI (with Toyota) GM's next step was to "emulate Japanese manufacturing methods without a Japanese joint-venture partner" (Jürgens 1998b:326). Opening in 1990, at Opel Eisenach these "experiences and human resources" were primarily provided as "a core group of General Motors managers for Eisenach who had hands-on experience under Japanese management in these various joint ventures with Japanese companies" was recruited to help in creating the Opel Eisenach Production System (ibid.). As a main function, these managers contributed to the "parenting/facilitating configuration" promoting a distinct Eisenach approach, which consisted of configuration based on four cornerstones:

- Pairing up American and Canadian managers with transplant experience with German managers with line authority
- The integration of central planners from the Technical Development Centre (TDC) in Rüsselsheim
- Role of Opel's chief executive officer, Louis Hughes who consolidated the divergent interests in the dual structure between the German technical planners, the German managers at Eisenach and the foreign transplant advisors
- The role of the works council at Opel Eisenach, particularly the head of the works council, a "true believer in the principles of the new system" (ibid.: 327) who, as a member of the metal workers union (IG Metal) reconciled this distinctly Eisenach approach with the interests of workers.

To focus in detail on the issue of the evolution and transfer of the TPS, it is important to point out that apart from the Eisenach plant manager La Sorda (recruited from CAMI), most of the transplant-experienced managers functioned as consultants/advisors. According to Jürgens, Eisenach drew "on around twenty advisors serving three year terms" (ibid.). Their advisory impact also extended to the central planning department located at Rüsselsheim and they "immediately made clear that they were to be involved in the process and insisted on demanding alternative solutions in many instances" (ibid.). Trying to balance these "divergent forces", Hughes, Opel's CEO attended all planning meetings making sure that the planners "would stick to its mission of developing a true lean production system" (ibid.). The "Eisenach Production System" was the result of various influences ranging from "General Motors' European production networks and markets, of lean-production-inspired local experiments and ideas transferred from transplant practice mostly in North America" (ibid.:329).

Regarding the transfer of TPS, Jürgens suggested that standardisation primarily occurs in the process organization and methods. For example, "employees conduct their own time studies, write and revise their standard operation sheets, and pursue continuous improvement activities" (ibid.:330). Moreover, the production flow is ensured by an assembly line, work organization is based on team-work, highly standardised instructions regulate how tasks are to be performed and define the content and extend of staff training (Reitz 1998:134). However, Eisenach is not a clean sheet copy of TPS. The Eisenach production system (EPS) is the result of "synthesizing a specific plant concept dedicated for small cars, a specific process layout and technology, and a very low degree of vertical integration, with a system of work, production and organization, and personnel policies adopted selectively from the various GM-Japanese joint-venture transplants and from other GM/Opel plants" (Jürgens 1998b:333).

Allowing thus to overcome the essential dichotomy of global standardisation (Reitz 1998:135), on the one hand, and the standardisation based on the local context (ibid.) on the other, Eisenach became the hub for transferring lean production standards, the nucleus for building new plants and GM managers from around the world are trained there (ibid.). Although the Eisenach Production System is not a cookery book from which separate recipes can be taken and implemented in new plants (ibid.:134). GM plants in Polen, Thailand, China or Argentina, do have similar building and facility structures which determine the standardised layout of machines and systems (ibid.:135).

From the historical development of Toyota and the evolution of the Toyota Production System, two central conclusions can be drawn so far. First, the TPS is the result of a company specific effort to define and formalise complex elements of production into one company-specific production system. Unlike the scientific paradigms of Taylorism and Fordism, the TPS consists of a system of "firm specific patterns of routine capabilities" (Fujimoto 1999:58).

Second, TPS evolved over time and is the result of a "cumulative and evolutionary" rather than a "revolutionary" process (ibid.:49). Striving for constant improvement, the elements of the TPS and therefore the entire system is part of an ongoing process of refinement (ibid.). According to Fujimoto, TPS evolved through a historical process defined as multi-path systems emergence, shaped by the "the interplay of both intended and unintended consequences" (ibid.:8). In combination with Toyota's specific "routine capabilities", the multi-path system emergence facilitates what Fujimoto calls an "evolutionary learning environment" (ibid.:58). Learning is considered a central aspect of the TPS (Jürgens 1994, Kenney & Florida 1993, Nonaka 1990), as I shall now discuss when looking at the forms and functions of standardisation in the Toyota Production System.

3.5.3 The forms and functions of standardisation in the TPS

According to Jürgens the Japanese model is characterised by a link between the system of production control with work and social organisation (Jürgens 1989b:21). In this model, Toyotism, represents a particular system for regulating work, not as an alternative to Fordism but an intensification of Fordist principles of organisation (Jürgens 1994:195). It is based on the complementarity of, on the one hand, a certain degree of self-regulation, involvement and participation of the worker in the working processes, and on the other, a complex system of social integration and social control (Jürgens 1989a). Amongst authors that have attempted to define the term "lean production", Jürgens states that lean production is "a set of new practices and new forms of work and process organisation" (Jürgens 1995a:298), in which the social organisation, particularly the organisation of work corresponds with the requirements of the process chain (Jürgens and Jansen 1999:35). The following diagram adopted from Monden's publication *The Toyota Production System*, gives a systems overview showing the inputs and intended outputs (cost, quality and quantity and respect for humanity):

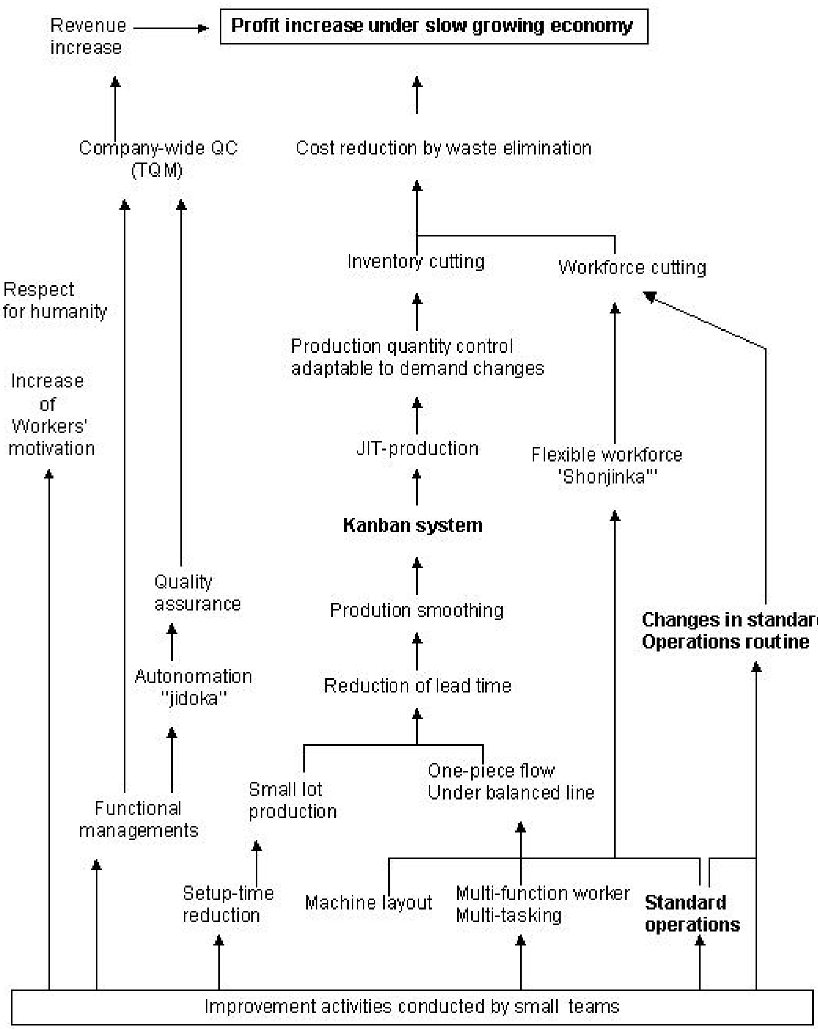

Fig. 3.1. How costs, quantity, quality and humanity are improved by the Toyota production system (source: Monden 1983:4)

Monden, as well as Nonaka and Jürgens have stressed the importance of the interrelation between these elements, particularly the interplay between features of the process organisation with features of the work organisation (Nomura and Jürgens 1995:16). For example, standard operations are continuously improved as part of the activities performed by small teams. This leads to a change in the standard operations routine and has direct repercussions on the size of the workforce, as operations are thus rationalised. This leads to a cost reduction and an elimination of waste (i.e unnecessarily high number of workers and unnecessary and unproductive steps in the work). As a result, profit increases, even despite negative economic indicators, such as a slow growing economy.

Standardisation and the refinement of standards play a key role in this dynamic process and Fujimoto suggests that "part of Toyota's dynamic capability may be ascribed to standardisation and documentation" (Fujimoto 1999:267). Standards within the TPS are not considered fixed but are subject to a continuous improvement process. This dynamic nature of standards provides the fundamental basis for the continuous improvement process. By encouraging workers to continuously refine and improve standards, continuous learning takes place. Thus standardisation, learning and CIP are at the core of the TPS. Two key objects of standardisation within the TPS are the standardisation of operations (standard operations routine sheet and the standards operation sheet), and the standardisation of the production flow facilitated by the Kanban system.

3.5.3.1 Standard operations

The main aim of the TPS is "to eliminate through improvement activities various kinds of waste lying concealed within the company" (Monden 1983:1). Both excessive inventory and staffing levels are considered wasteful (ibid.:145). Standards regulating operations therefore aim to minimise the number of workers in production neither jeopardising product quantity nor quality (ibid.). They also ensure that the available workforce is deployed efficiently and therefore regulate a "sequential routine of various operations taken by a worker who handles multiple kinds of machines as a multifunctional worker" (ibid.:11).

According to Monden, standard operations at Toyota have three main goals. First, they ensure productivity levels through efficient work. This is achieved by standardising the steps of the work routines, formulated in a standard operations routine, thus reducing the amount of "wasteful motion" (ibid.:145) for the worker. Second, standard operations aim to balance processes across lines in terms of production timing. This is facilitated by incorporating the "cycle time concept" into the standards operations (ibid.). Third, the standard quantity of work-in-process is limited to a minimum thus aiming to reduce buffers through potential work-in-process inventories (ibid.). The following overview summarises these key elements of standard operations at Toyota.[14]

[14] The three main goals are also supported by standards regulating the sub-goals of accident prevention (safety measures) and defective production (quality control).

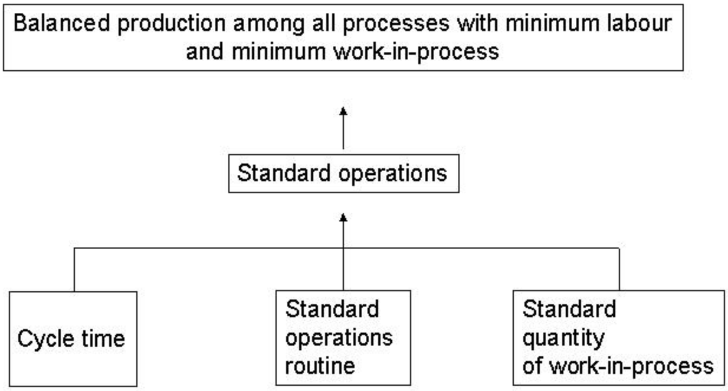

Fig. 3.2. Elements of standard operations (source: Monden 1983:146)

These routines are formalised by two written documents: the standard operations routine sheet and the standard operation sheet (ibid.:11). According to Monden, the former represents a "man-machine chart" (ibid.) mapping the link between the physical motions of the worker with the mechanical operations of the machine. It defines the "sequence of operations that should be taken by a worker in multiple processes of the department" (ibid.). The steps involved in the operation of each machine, commencing with the picking up of material, feeding and finally detaching the processed material, is listed in sequence for each machine the worker handles. All necessary steps of these operations have to be completed within the cycle time set.

The standard operation sheet, specifying "cycle time, standard operations routine, and standard quantity" (ibid..48) is "posted above the work stations" (ibid.:64) visible for all workers. Cycle time represents "the standard specified number of minutes and seconds that each line must produce one product or one part" (ibid.:11). It is deduced from the monthly market demand forecast and thus follows a push system (ibid.). Based on this information, management derives the minimum staffing levels needed (ibid.).

Both, the standard operations routine sheet and the standard operation sheet are elements of Toyota's standard operations. According to Monden, "the components of standard operations are determined mainly by the foreman (supervisor) " (ibid.:145). Nomura and Jürgens define the role of the Hancho (Team leader) as contributing manual skills, and the Kumicho (group leader) as contributing production knowledge and experience (Nomura and Jürgens 1995:110ff.).

The former being responsible for the induction (ibid.:111), the latter is responsible for quality insofar as he is responsible for setting standards for methods and times (ibid.:112). Regarding the practical task of establishing standard operations, it is thus assumed that these are performed by the Hancho (ibid.:111). Part of the task is to calculate the necessary labour time and to structure the sequence of operations to be performed by the workers. Since Ford's days, this had been the prerogative of the Industrial Engineer, placing the responsibility for standard operations into the hands of the scientific engineer, rather than the supervisor on the shop floor. According to Monden, at Toyota it is the responsibility of the Kumicho to: calculate cycle time, determine completion time per unit, standard operations routine, standard quantity of work-in-process, and to prepare standard operations sheet.

Regarding the first two items, with the help of mathematical formulas and timing devices such as stop watches, foremen arrive at standards for the cycle time and the completion time per unit. The former denoting "the time span in which one unit of a product must be produced" (Monden 1983:146). It is derived by dividing the actual daily operating time by the required daily output quantity. Unlike the net daily operating time calculated in other companies, at Toyota, no allowances and adjustments for "machine breakdowns, idle time awaiting materials, rework or for fatigue and rest time" (ibid.:147) are made.[15]

The completion time per unit (the required time to produce one single unit), is part of range of standard measures used to determine the production capacity (Monden 1983:147). Together they are individually listed in the part production capacity sheet. The completion time per unit is measured "for each process and each part" (ibid.) and consists of the manual operation time plus the machine automatic processing time (ibid.:148). In addition times for tool exchanges and the quantity of units produced with one tool are recorded. Production capacity as units of output is thus calculated by dividing the total operations time by the sum completion time per unit and set up time per unit.

The information generated on the part production capacity sheet is essential for the determination of the standard operations routine. Having established the manual and machining times for each product and process, the supervisor now determines the "order of actions that each worker must perform within a given cycle time" (ibid.:149). According to Monden, the setting of this routine has two functions. First, it structures the worker's tasks according to a routine sequence. This standardised sequence starts with the worker picking up the material. He then feeds the material into the machine. Finally, the worker detaches the processed part from the machine (ibid.). Second, the standard operations routine provides "the sequence of operations that the multi-functioned worker must perform at various machines within a cycle time" (ibid.). Thus, the order in which the machines are fed within the cycle time is established (ibid.). The part production capacity sheet plays a vital role in this process as it contains the different machining process times which have to be considered, for "the automatic processing time of a certain machine will be finished before the worker handles the same machine in the next cycle of the tact time" (ibid.). Working backwards from the cycle time, the individual steps necessary in the process are analysed according to three time measures: manual operation time, machine processing time and slack time (walking time from one machine to the next). Workers adapt this standardised routine

[15] See also Nomura and Jürgens 1995:151.

only once "the foreman can comfortably finish it within the given cycle time" (ibid.:151). In practice and in the case when setting cycle times for a new production run, Nomura and Jürgens suggest that the practical tests regarding the feasibility of new standard times and routines are conducted by the Hancho because they have most experience with production tasks (Nomura and Jürgens 1995:149).

After having established the standard operations routine, in order to achieve a smooth production flow and the "rhythmic operations of various machines" (Monden 1983:155) in one line, the minimum work-in-process quantity within the particular production line has to established. According to Monden, the standard quantity of work-in-process consists of "the work laid out and held between machines" including the work "attached to each machine" (ibid.). In line with the goal of the TPS, the amount of work between machines should be zero, providing for a system of one-piece flow in which "only the work attached to each machine is necessary" (ibid.).

The final part of the standard operations of the TPS is the standard operations sheet. It brings together and visualises the described items above but also includes aspects regarding quality inspection and work place safety. The standard operations sheet consists of six types of information: "cycle time, operations routine, standard quantity of work-in-process, net operating time, positions to check product quality and positions to pay attention to worker safety" (ibid.:157). The standardised operating sheet offers a visual control tool for worker, supervisor and management. First, it represents a visualised guideline for the worker to follow. According to Fujimoto the visualisation of standards aid the understanding of what, how and in which sequence the worker has to perform tasks (Fujimoto 1999:293). Second, it serves as a check up (Monden 1983:155) or control tool for the supervisor who is now able to compare the actual work performed by the worker and the standardised task performance description (Fujimoto 1999:64).

Third, once standard operations are set, it is the supervisors and workers task to continuously improve these standards. A potential failure to update and improve the standards operating sheet signals management that they fail to actively contribute to the continuous improvement process (Monden 1983:157). As a control tool, the visualisation of the standard operations thus drives home, what Monden considers to be the "most fundamental idea behind the TPS", namely that the "progress of a company can be achieved only by continuous efforts on the part of all members of the company to improve their activities" (ibid.:158).

3.5.3.2 The kanban system

Whereas standard operations regulate the time, motion and the sequence of tasks to be performed, "the kanban system is an information system that harmoniously controls the production of the necessary products in the necessary quantities at the necessary time in every process of the factory and also among companies" (ibid.:15). Whereas in traditional Fordist *push systems*, one process supplies parts to the next, the kanban system at Toyota is based on a *pull system* in which "the subsequent process will withdraw the parts from the preceding process" (ibid.:16). The kanban system serves as an information system informing "all processes about necessary timing and quantity of parts production" (ibid.). In addition to harmonising "production quantities in every process" (ibid.:6) and synchronising "upstream and downstream processes" (Fujimoto 1999:59), both kanban components (such as layout and size of kanban cards) and the kanban procedure (kanban post and kanban rules) are highly standardised thus facilitating that workers learn to blindfoldly handle the ordering and materials supply system.[16]

The term "kanban" alone refers to the "tag-like card that communicates product information" (Japan Management Association 1985: preface). Each card is displayed in a "rectangular vinyl envelope" (Monden 1983:16). There are two types of kanban: the withdrawal kanban regulating "kind and quantity of product which the subsequent process should withdraw from the preceding process" (ibid.); the production-ordering kanban stating the "kind and quantity of product which the preceding process must produce" (ibid.). On the withdrawal kanban, for example information is listed about the store and shelf number, kanban number, box capacity and item number. The ordering kanban only lists information about the item and the shelf.

Focusing on the withdrawal kanbans, the heavy triangular kanban made of metal is used to specify and signal lot production (Monden 1983:19). It contains information about the required lot size, the part name, the reorder point (the point indicating when the part is to be produced), pallet number, part number, store and machine number to produce the part. This triangular kanban is placed into a signal kanban box together with the material-requisition kanban used to signal the order for the actual materials used to produce the required part (ibid.).

The basic principle behind the kanban information flow is based on a highly standardised process in which basically production-ordering kanbans are exchanged by withdrawal kanbans and vice versa, thus "carefully comparing the withdrawal kanban with the production-ordering kanban for consistency" (Monden 1983:21). The kanban system is enforced by so-called five "kanban rules" (Monden 1983:24ff., Japanese Management Association 1985:87ff.):

1. "The subsequent process should withdraw the necessary products from the preceding process in the necessary quantities at the necessary point of time.
2. The preceding process should produce its products in the quantities withdrawn by the subsequent process.
3. Defective products should never be convened to the subsequent process.
4. The number of kanbans should be minimised.
5. Kanban should be used to adapt to small fluctuations in demand (fine-tuning of production by kanban) " (ibid.:24ff.).

The supplier kanban system, too, is organised according to a standard time schedule. For example, the incoming lorry to the supplier delivers empty kanban boxes and supplier kanbans to the supplier's store at 8 am. The driver then switches trucks and takes the completed parts (including their respective kanbans) which

[16] Also related to the blindfold return tool cabinets as presented by Monden 1983:212.

had been ordered by Toyota at 10 pm the previous night, back to the Toyota plant, once at Toyota, the cycle commences.

Supporting the kanban system, Toyota has installed switches and visual demarcations to signal standard amounts. The Japanese Management Institute cites the example of limiting the standard stock of one particular machine to five units and "if there are only three units, the preceding process automatically begins to process and continues until the quantity reaches five units" (Japanese Management Association 1985:96). The kanban system thus functions as a "limit switch" (ibid.:97). It serves as a "work order" and as the process description and the examples have shown, the kanban system is an "automatic directional device" (ibid.:85). The kanban system represents a simple human information system with standardised formats of kanbans, colours, sizes, numbers and processes. It is a system which workers learn to handle blindly. According to the Japanese Management Institute, the kanban thus serves workers to "engage in standards operations at any time" (ibid.:86).

3.5.3.3 Continuous improvement (kaizen)[17] and learning

Standard operations and the kanban system are two elements of the Toyota Production System providing standardised framework of process and work organisation. However, they are not static standards but are subject to the continuous improvement process (CIP). The purpose of the CIP is to eliminate any wasteful activity thus contributing to the key goal of the TPS "to increase productivity and reduce manufacturing costs" (Monden 1983:177). Standard operations and the kanban system therefore do not represent fixed, static solutions but are subject to a continuous process of improvement, as the diagram below visualises:

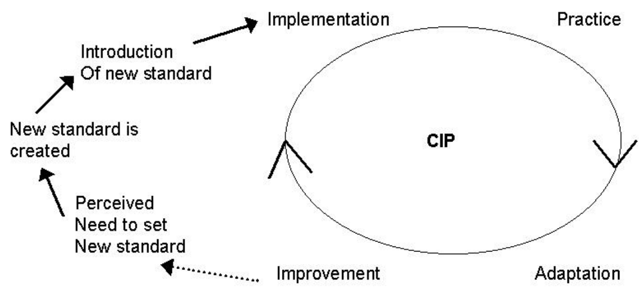

Fig. 3.3. Standardisation and the continuous improvement process in the Toyota Production System

[17] Fujimoto 1999:287.

Pertaining to cycle time, this represents a fixed time which is not revised even if the work process has been improved or technical processes have been changed (Nomura and Jürgens 1995:150). However, if improvements in manual operations can be made, the standard operations routine sheet and the standard operation sheet are changed. These changes are part of the responsibility of each team. The tasks of the team, according to Nomura and Jürgens contain direct production tasks, indirect tasks, quality assurance and material handling tasks, as well as induction training, continuous improvement activities and from a human relations perspective, integrative social tasks (ibid.:244).

Concerning their contribution to the continuous improvement of standards – an aspect I shall come back to in context to the Adler and Cole and Berggren debate - Nomura and Jürgens suggest that the key function of teams and groups concerns personnel development, qualification and social integration of new staff at the beginning of their career in the organisation and are but one element in a carefully construed tense networks which represent the core of the dynamic drive towards the continuous improvement of product, production processes and work on the shop floor. According to the authors, it is this dynamic tension between social control and social integration, between competition and cooperation, between the pressure of selection and privileges, which spur on the individual to give a top performance (ibid.). Moreover, these internal team dynamics are formally enshrined in the TPS by linking the continuous improvement process and the system of remuneration (ibid.:170). Nomura and Jürgens suggest that the actual work performed is only one part of the assessment. The contributions made in the continuous improvement process and activities, the cooperation within the team, the social competence and the ability to lead and to motivate team members and subordinates are further criteria in the performance appraisal (ibid.:246). The wage level of each worker is therefore directly linked to his contribution to the continuous improvement process and the overall success of the company (Shimizu 1995). According to Nomura and Jürgens, the pressure to improve productivity is driven by competitive mechanisms, such as the ranking achieved in the productivity league table, and hence the thus related effect on compensation (Nomura and Jürgens 1995:165). Toyota's remuneration system enshrines this link as productivity is at the centre of any activity within the organisation. The core aim of the organisation is the continuous improvement of productivity. (ibid.:170). [18]

Moreover, productivity is seen as contributions to the continuous improvement process by both the individual worker and the group. In its idealised form, kaizen activities drive a learning spiral shop floor - experts - shop floor is thus initiated. Thus the dynamic process of standardisation is internally generated by individual workers and within groups (Jürgens 2002:4). Jansen and Jürgens interpret the function of the group within Toyota as a means to increase productivity (Jansen and Jürgens 1999:35) and is used to exploit informal aspects within group relations for this purpose (Jürgens 1989b:21). According to Nanto, "each person de-

[18] For details about how remuneration is calculated at Toyota and its role as competitive factor, please refer to Jürgens and Nomura 1995: 135ff.

pends on each other person to do the job well. If one person slacks off or does not show for work, it places a burden on others" (Nanto 1982:8).

The dynamic effect of the dependence of the individual on the group is, for example particularly evident in the external process pressure exerted by the kanban system. According to Schonberger, large lot sizes and buffers can "provide a convenient rationalization for carelessness" (Schonberger 1982:28). With small-lot size inventory though, "one worker's problems threatens to bring subsequent processes to a halt" (ibid.:29). This poses a potential threat on the productivity achieved by the group and a subsequent decrease of the productivity component of their wages. Thus this process constraint in combination with a potential loss in wages forces the workers to co-operate. This also applies in the case of the Just-in-time system as it represents another external process pressure on the work of the actors on the shop floor.

So far about standardisation as external process pressure in the Toyota Production System. But what about the aspect of learning as part of this process?

As delineated in the history of Toyota at the beginning of this section, the TPS evolved over decades, a process in which according to Fujimoto Toyota developed its "evolutionary learning capacity" (Fujimoto 1999:5). The formalisation of the TPS is part of this process as it reflects Toyota's "ability to evolve competitive routines even in highly episodic and uncertain situations" (ibid.). Moreover, the standard elements of the TPS as discussed above, can be explained in terms of reflecting Toyota's "routinised learning capability" (ibid.:19); that is a company's specific "ability of handling repetitive problems solving cycles or a routinised pattern of system changes" (ibid.:17). Thus, standard operations and the kanban system represent organisational routines for "problem identification, problem solving and solution retention" (ibid.:19). Continuous improvement facilitates the ability of individuals and groups to "to formalize and institutionalize new solutions in standard operating procedures, thereby providing stability for individuals who internalise solutions" (ibid.).

In Fujimoto's description of Toyota's organisational routines, standard operations and the kanban system represent information systems. They provide a medium in which information is transformed, transferred and transported (ibid.:88). The process of information processing is driven by the CIP. According to Kenney and Florida, "this creates a powerful learning dynamic and enhances the problem-solving capabilities at the enterprise level" (Kenney and Florida 1988:132). Nonaka, explains this dynamic with the systematic tapping of the tacit knowledge of the worker as facilitated by the CIP process. This plays a key role in giving Japanese companies their competitive edge and "the centrepiece of the Japanese approach is the recognition that creating new knowledge is not simply a matter of 'processing' information. Rather, it depends on tapping the tacit and often highly subjective insights, intuitions, and hunches of individual employees and making those insights available for testing and use by the company as a whole" (Nonaka 1991:24). Dohse et al. conclude that for Japanese companies the "Taylorist reduction of the intellectual demands made on the workers is no longer the maxim" but rather, that they use their workers' "intellectual capacities for the goal of production" (Dohse, Jürgens, Malsch 1985:124).

According to Fujimoto "tacit knowledge is an attractive way of explaining the firm-specificity of manufacturing systems because it obviously does exist on real-life shop floors" (Fujimoto 1999:16). For Nomura and Jürgens the efficiency of the TPS is based on a reconciliation between standardisation and learning. On the one hand, know-how to solve problems is stimulated and the contribution of individuals in problem solving processes is encouraged; on the other, discipline, rigid working structures, highly repetitive and standardised tasks determine the system (Nomura and Jürgens 1995:253). The willingness to submit to this system is ensured by establishing a linking of the CIP with the remuneration system and thus extraordinary performance is expected (Jürgens 1989a). Jansen and Jürgens point out that this adds physical and psychological strain on the worker (Jansen and Jürgens 1999:36) and the process pressure is a constant, chronical pressure on the individual (Jürgens 1993:10).

In contrast, Adler and Cole suggest that "this constant improvement effort creates a certain level of stress, but as the worker attitude surveys show, the level is not so high as to degenerate into strain and distress" (Adler and Cole 1993:5). Indeed, their research conducted at the joint venture between Toyota and GM at the New United Motor Manufacturing Inc. (NUMMI) (Adler 1992, Adler and Cole 1993 and Adler 1993), "flies directly in the face of" (Adler 1993:98) the human relations argument. Instead, Adler and Cole perceive that the TPS, deployed at the Toyota-General Motors joint venture plant NUMMI, provides standards and procedures "that are designed by the workers themselves in a continuous, successful effort to improve productivity, quality, skills and understanding" and are thus able to "humanize even the most disciplined forms of bureaucracy" (ibid.). The NUMMI plant is thus a "learning bureaucracy" and a prime example of "democratic Taylorism" (Adler 1992). Instead of perceiving standards as a coercive force, according to Adler and Cole, at NUMMI standards provide a "logic of learning, a logic that motivates the workers and taps their potential contribution to continuous improvement" (Adler 1993:98).

As already discussed above, whereas in other companies, the Industrial Engineers conduct time and motion studies, at NUMMI this prerogative is handed onto the shop floor. Being taught the principles of time and motion studies, workers conduct work analysis, improve work routines and thus are responsible for setting and continuously improving standards:

> "Team members begin by timing one another with stopwatches, looking for the safest, most efficient way to do each task at a sustainable pace. They pick the best performance, break it down into its fundamental parts, then explore ways of improving each element. The team then takes the resulting analyses, compares them with those of the other shift at the same work station, and writes the detailed specifications that become the standard work definition for everyone on both teams" (Adler 1993:103).

This process involves all team members and thus Adler claims it improves "worker motivation and self-esteem" (ibid.). For the author, "standardised work is simply a means of reducing variability in task performance" thus improving work place safety, quality, process flows, job rotation and flexibility (ibid.). As workers perform the tasks once handled by Industrial Engineers, they acquire new skills initiating a learning process. Standardisation is provides the "stimulus" in this process (ibid.:104).

This led Adler to go as far as considering standardisation as "essential precondition for learning" (ibid.). Moreover, including the tacit knowledge of the shop floor directly into the standard setting process, each worker and each work station represents a "centre of innovation" (ibid.). The innovative ideas are directly incorporated into standards as workers, together with "leaders and engineers create a consensual standard that they teach to the system by writing job descriptions" (ibid.). In turn, the "system then teaches these standards back to workers, who, then, by further analysis, consultation, and consensus, make additional improvements" (ibid.). This "continual reiteration of this disciplined process of analysis, standardisation, re-analysis, refinement and re-standardisation creates an intensely structured system of continuous improvement" (ibid.). Driven by the continuous improvement process, the organisation learns to "change its routines to adapt better to the environment" (Fujimoto 1999:21).

Adler and Cole's stand was challenged foremostly by Berggren (1992) and other academics propagating a system of "holistic" or "reflective" manufacturing,[19] I shall discuss in the next part.

In sum, the TPS represents a next step in the evolution of production systems. One has to distinguish between the original TPS (TPS 1), as analysed by Jürgens and Nomura), its evolution during the 1990s (TPS 2), as analysed by Shimizu.[20]

The initial, "classical" TPS (1) was marked by the intention to constantly improve processes and standards with the goal of reducing any form of waste, be it faults or unnecessary movements at the workplace. The organisation of work in teams but also standards regulating operations, the kanban system or the pay system all aid this continuous improvement process.

Based on the classical systems descriptions of Ohno, Monden and Imai of the TPS 1, in my view, the importance of the workers on the shop floor for the refinement of standards is of key importance. In its ideal form, kaizen initiates a learning spiral shop floor - experts - shop floor. Insofar, the dynamic process of standardisation is internally generated. By contributing to the refinement of standards, the know-how and experience of each actor is integrated into the standards of the TPS: the individual worker is thus able to set best practice standards and hence can influence existing standards. Standards in the TPS represent initial marks, specifications about how processes are to be structured which are then assessed and improved by workers. Hence, initially in the TPS 1, standards provided

[19] Berggren 1992 In the publication *Alternatives to Lean Production*, Berggren accuses Adler and Cole for deducing their theory merely from a series of static snap-shots at NUMMI; a theory according to the author which is but a "revamped and intensified" version of Taylorism: "rigid standardisation, minute subdividison of labor, short-cycle tasks and narrow job roles".

[20] Currently, the plant at Onnaing represents a further step in the evolution of TPS1 concerning process layout, and also a further development of the TPS2 concerning the CIP-process being increasingly expert-driven.

an input, an improvement opportunity which then allows the worker to bring in his know-how and experience to refine them. Most significantly, the willingness and understanding that standards need to be subject to constant improvements, are enshrined in the attitude of the workers. The TPS 1 promotes an attitude of striving for constant improvement. As a result of the inclusion of the know-how and experience of the workers in standards, this knowledge is shared and hence the TPS contributes to the creation of an "evolutionary learning environment" (Fujimoto 1997:58).

One often neglected aspect concerning the introduction of standardised production systems is the fact that the Toyota Production System has evolved further. In fact, the TPS 1 has meanwhile developed further from the image we still have of it (Jürgens 2002:14). With the emergence of the crisis of work during the "bubble economy" period, Toyota launched a "humanization of the production system and of work" (Shimizu 1995:400) at its Kyushu plant in 1992 (Fujimoto 1999:225). The "human-friendly" "new Toyotism" (Shimizu 1995:401) might be far removed from the reflective production system of Uddevalla, I shall come to now, however, it represents an attempt to "escape from the fatalism of the assembly line and to give a more humane dimension to assembly work" (ibid.). Toyota intended to humanise its production system and work at the Kyushu plant, by "improving working conditions, by developing a new conception of the production line, by allowing segments of the line to keep buffer stocks, by making social relations of work more equitable and rational" (ibid.:400),

3.6 The reflective production system of Volvo Uddevalla

The name Uddevalla stands for a concept of production, which instead of focussing on technology and production, is primarily concerned with the human being within production. (Jürgens 1998a:1). Its roots date back to the 1970s when the Volvo Truck Operation experimented with the team work concept in the assembly of "complete trucks at a stationary dock station" (Ellegård 1997:192). Pehr Gyllenhammar, who in 1972 took over the post of CEO at Volvo, restructured the corporation into decentralised units, Gyllenhammar intended to "democratise the corporation from top to bottom" (Rehder 1992:61). The assumption being that structural changes inside the organization facilitate the implementation of socio-technical systems in production. The layout of the assembly line and the material flow played a key role in the evolution towards the reflective production system of Volvo Uddevalla.

3.6.1 Creating the reflective production system at Uddevalla

According to Engström, Jonsson and Medbo (1999), work cycle times determined by Industrial Engineers through time and motion studies represent a mere "theoretical abstraction of a complex reality" (Engström, Jonsson, Medbo 1999:194).

These set times "fail to accommodate inter-operator and intra-operator variation" and contribute to generating "idle operator time and/or need for re-work" (ibid.: 193). In order to eliminate this waste of working time, either a "parallel flow assembly system" or a system of buffers between workstations has to be established in order to smooth these variations (ibid.:194). In addition, to these technical solutions, Engström et al. suggest that by braking down the strict division of labour, and encouraging workers to help each other, work will be performed ahead of schedule (so-called working-up) (ibid.). Thus new assembly system designs need to promote "group work as well as working-up" (ibid.:195). The authors suggest that the answer lies in the introduction of a parallel flow assembly system which takes account of combining the "operator needs and priorities with management requirements for efficiency, quality and flexibility" (ibid.).

Moreover, the rigid time and motion standards are done away with as "work groups will tend to develop their own norm system with regard to quantity and quality goals, how to handle sick-leave, etc. " (ibid.). In conjunction with a traditional serial flow, the first attempt to introduce this parallel flow assembly line was undertaken at the Kalmar plant in 1974 (ibid.:199). The layout was based on 27 work groups initially separated by intermediate buffers (ibid.). Using a mixture of serial and parallel flows, assembly systems were "winding around the outer walls of the plant" (ibid.). According to Medbo et. al this was done to enable workers to "stand by the window and perform traditional assembly work using a costly and complex AGV-system (Automatically Guided Vehicles) to carry the automobile bodies" (ibid.). The materials flow was standardised insofar as materials were supplied by a two-storey high materials store located at the centre of the plant (ibid.), a feature later to be adapted at Uddevalla. In 1987, in order to adapt to the longer assembly time required for the Volvo 760 model, the Kalmar plant was extended and "intermediate buffers were largely eliminated, since most AGVs in the buffers had to be converted to work-station use" (ibid.:200). These changes increased production flexibility as changes in the production sequence could be made during the production run, and turned Kalmar into a line assembly system (ibid.). Driven by the need to improve work place ergonomics, in 1989 a parallel flow assembly was introduced in the subassembly of engine and gearbox (ibid.). While the experiments with the assembly line lay out at the Kalmar plant were primarily seen to aid Volvo's public relations, its system of elastic serial flow allowing flexibility of production pace and product sequence, inspired and evolved into a system of rigid parallel flows at Volvo Uddevalla.

Encouraged by the positive development of its export sales and the prospect of generous state subsidies for the conversion of the former Uddevalla wharf into an automotive, Volvo decided to build a new assembly plant primarily for its 740 model in 1985 (Jürgens 1998a:2). Developing from its previous experiences at Kalmar, the production system at Uddevalla placed human considerations at its centre. According to Jürgens, the creation of this reflective production system was aided by three circumstances (ibid.). First, decreasing unemployment figures and Swedish government regulations promoting full employment were feared to result in problems of work force fluctuations and absenteeism; the repeat of a situation as witnessed during the 1970s when the fluctuation rate amounted to 28.1% at

Volvo's main plant in Torslanda (ibid.). By creating a more human working environment Volvo intended to curb potential labour fluctuations. Second, Volvo's CEO Gyllenhammar recognised that the plant at Kalma is not an ideal work shop. It is a first step towards a new organisation. But concerning new working structures, a lot remains to be done, particularly concerning the degree of freedom and independence workers have over their own work and working processes (Gyllenhammar 1991:143). Thus the intention to support the new production system at Uddevalla, received top management support. Third, in addition to receiving support by the employer side, the unions increasingly began to focus on issues of work organisation and quality of work. At the congress of the Swedish unions in 1985 a programme called the good work had been ratified. The support for the creation of a more human working environment and production systems was extended to a further programme called "Solidarische Arbeitspolitik für die gute Arbeit" (solidary work policy for good work) in 1989 (Jürgens 1998a:3). Thus both, the interest of employers and labour representation encouraged the development of a new production approach.

The first planning concept was based on Volvo's Kalmar plant which consisted of partly parallel, partly serial work processes and cycles of 20 minutes (ibid.:5). However, Gyllenhammar rejected this proposal paving the way for academic consultants to realise their ideas and concepts (ibid.). The output capacity of Uddevalla was set at 40.000 units annually based on an eight hour shift. In addition to setting the production target, six key goals the assembly at Uddevalla had to achieve were agreed upon. The underlying objectives of the production system at Uddevalla were to ensure quality, flexibility, overall efficiency (Ellegård 1997a:191, Jürgens 1998a:3). In addition, work at Uddevalla should offer the best possible development opportunities for staff, a flat hierarchical structure and work should be based on the concept of group work, namely the creation of the smallest possible self-efficient units (Jürgens 1998a:3).

In December 1987, the production plans based on a parallel flow assembly system or complete assembly were decided. The first production work shop (PWS) started in August 1989, and the set up phase was concluded as the final fifth PWS commenced in October 1990. The planning and setting up of Uddevalla thus took almost six years, yet the decision to close the plant was made two years later, in November 1992 and the last car left the Uddevalla plant in May 1993. Since then Volvo together with its joint venture partner TWR, decided to re-open the plant, now named Autonova and production of the so-called Uddevalla II assembly commenced in June 1997.

3.6.2 The role and function of standardisation in the reflective production system

The Uddevalla plant consisted of six parallel assembly workshops grouped around two test shops (Engström, Jonsson, Medbo 1999:200). The production flow was regulated by a standardised system of materials supply. Adopted from the Kalmar plant, at Uddevalla a centralised, "separate materials workshop prepared materials fixtures" (ibid.). The parts for each vehicle were combined as individual kits, configured for assembly on special material handling containers. These kits were precommissioned in the materials workshop and from there were delivered directly to the various assembly workshops (Engström, Jonsson, Medbo 1999:201). According to Engström et. al., "the hardware (structure) was identical though the number of plastic containers and the actual materials in the fixture differed" (ibid.:218). These commissioned kits for each individual car are ordered and thus serve as assembly description for the workers (Jürgens 1998a:6). The commissioned kits according to Ellegård also contributed to the aspect of learning as, "if the components were given to the assembly teams in the form of previously prepared material kits (with the components arranged exactly for the specific tasks of the assembly team), then the extended assembly work became easy to learn and perform" (Ellegård 1997a:195).

Engineers in the planning group developed this idea and suggested that "they prepare kits of 1/8th of the car, corresponding to a cycle time of around 20 minutes" (ibid.: 195). However, in accordance to holistic learning principles, to assemble only 1/8th of a car is "too limited to reap the potential generative effects of these principles" (ibid.). Instead, the minimum assembly competence level was estimated to be at least 25% of the Volvo car, because "only then could each worker relate his own part of the work to the whole – the essential idea behind holistic learning" (ibid.). These theoretical assumptions were also supported by practical experiments conducted which focused on investigating "the human potential for the learning of long work cycles" (ibid.). Two incidents provide practical examples of the application of this potential: a previously untrained worker "learnt to assemble a complete car using the principles of holistic learning and materials arrangement" (ibid.); a sixteen year old apprentice who after two weeks training managed to assemble on his own one quarter of the entire car at almost full production speed (Jürgens 1998a:6).

A second key aspect of the materials flow system at Uddevalla was the automatically guided vehicle (AGV) transport system which made it necessary that all fixture stands were standardised throughout all workshops. The link between this combination of a highly standardised system of materials supply on the one hand, and a highly individual work organisation in the workshops, on the other did not harmonise. According to Engström et. al. then, "the production scheduling system in Uddevalla allocated each individual order to a specific work group, defining a production sequence for each group. These sequences were synchronised to one planned overall sequence (standard) for the total plant" (Engström, Jonsson, Medbo 1999:219). However, Jürgens points out that this standardised material supply system could not be reconciled with a highly autonomous work organisation, "both the flexibility and performance were negatively affected" (Jürgens 1998a:7, Engström, Jonsson, Medbo 1999:219).

Regarding the organisation of work in each workshop, initially, the "provocative idea" initially was that 12 people assemble an entire car together (Ellegård 1997a:190), by 1986 though this idea was revised and according to Ellegård, around 50 to 60 workers in product shops were to assemble 25% of an entire car (ibid.). One year later, this number was reduced to 16-20 workers within one team zone and by 1988, around 7-10 workers working in one team were able to assemble one quarter of an entire car (ibid.). This system thus allowed each worker to structure his work according to his own preference, termed by Ellegård reflective production system as it drew on the "inherent human needs, abilities, and ways of learning" (Ellegård 1997b:321).

As a result, "large variations in work methods and work group sizes existed" (Engström, Jonsson, Medbo 1999:203). For example, in one group seven operators assembled an entire car in a work cycle time of 100 minutes, whereas in another workshop two female operators assembled an entire car "resulting in mean work cycle times in excess of 300 minutes" (ibid.:212). Ellegård points out that, in one case, each worker assembled one eighth of the car. The expectation being that each worker had the competence to assemble one quarter of the entire car (Ellegård 1995:132, also Jansen and Jürgens 1999:46).

In a survey conducted by Engström et al. (unpublished 1996) between August 1991 and October 1992, around 90% of assembly workers contributed to around 15% (1.2 hrs) work to the entire car. Just below two thirds worked in cycles of 2.4 hours contributing 30% of the assembly work on the entire car, around one third of workers worked in cycles of 3.2 hours contributing 40% or a cycle of 3.2 hours work. Around 30 workers had the certified skills to complete the assembly of an entire car. Regarding the assessment of their competency, workers rated work content and competence highest at a degree of assembly completion between 20 – 40% (Jürgens 1998a:9).

Regarding productivity, according to an estimate by Berggren, in January 1992 the assembly of one car took almost 50 hours. Nine months later, by November 1992, this figure had dropped to 32 hours (Berggren quoted in Jürgens 1998a:14). Compared to the Volvo Torslanda plant, the assembly hours for nine vehicles at Uddevalla averaged between 10.0 to 12.0 hours, whereas the assembly time for the same units in two lines at Torslanda were consistently around just below 16.0 and 17.0 hours (Jürgens 1998a:18).

Thus workers were allowed to "control their own pace of work," (Rehder 1992:9) and the team itself received a high degree of self-regulation. Initially, teams were intended to be structured "to balance ages and genders" (Rehder 1992:8), which according to Leif Karlsberg, head of the Uddevalla plant, served to "achieve greater social harmony and balanced values, experience and judgement within teams" (Karlsberg in Rehder 1992:8). However, the team soon regulated and decided on team composition, membership, replacements, selection and training of new team members. These examples show the extent of the increased self-regulation, autonomy and responsibility the team received at Uddevalla.[21]

Analysing the effect of this increased self-sufficiency of the teams, Jürgens also points out that the extension of the freedom to self-regulate work resulted in higher stress levels. In other words, although workers affirmed that the new production system had improved their influence on and control over work, and over-

[21] For an indepth analysis of the impact of autonomy on group work see Schumann, M., 1993:168ff.

all had created more stimulating work, on the other hand, the demands posed on them by the new system,[22] particularly the demands on their socio-emotional competence, were considered considerably higher than in the old system of mass production (Jansen and Jürgens 1999:47). This shows the importance for production systems to strive for a balance between providing a routine in terms of a framework and aid to structure work, which does however not cause work to become monotonous. Work structures provided by production systems as need to provide meaningful, varied work contents and comprehensive tasks, yet without overburdening the worker. The case of the reflective production system at Uddevalla points out the difficulties of achieving this balance.

According to the Engström et al. survey, around 50% of assembly workers rate the socio-emotional competence of their work as being relatively high. Regarding the challenges of physical versus intellectual/mental work, just below 50% of workers rated the demands imposed by physical work to be high, whereas more than 50% of workers perceived the intellectual competence demanded to be of an average level. These results were underscored by comparing the psychosocial factors influencing the work of Uddevalla workers with those of assembly workers in other companies (Jürgens 1998a:11). The results confirm the claim that Uddevalla represents a more human system of work, for Uddevalla workers consistently scored higher when rating their impact and control over their work, their relationship with superiors, the stimulation they receive through their work and their social relation with other workers. Overall then, around 50% of male assembly workers and more than 70% of female workers at Uddevalla are considerably content with their work (ibid.:12). These results apply specifically for those workers having worked for four or more years at the plant (ibid.:13). Concluding from their findings, Engström et al. list five advantages of the parallel flow at Uddevalla:

- Simultaneous assembly of different products and variants
- Selective introduction of new models in individual groups
- Work content increases through an extended cycle time thus encouraging staff to acquire new skills ("knowledgeable workforce") and hence being able to handle a diverse range of products
- Application of multi-purpose tools
- Necessary administrative support, such as variant specifications, increase transparency and "enhance flexibility" (Engström, Jonsson, Medbo 1999:217).

Concerning the quality of the products assembled, there were considerable differences in the quality of work between groups (Jürgens 1998a:31). According to Engström, "this variation in quality might be one of the negative aspects of the Uddevalla production principles" (Engström, Jonsson, Medbo 1999:214). However, for the sake of creating a human centred production system and to facilitate

[22] For a controversial research comparison between the job satisfaction under Volvoism and Toyotism refer to Adler and Cole 1993:85ff.

holistic learning, the authors also point out that "it is better to have a low variation in quality and a slightly lower average quality" (Engström, Jonsson, Medbo 1999:214). Interestingly, the authors also point out that there "was no really good explanation for this quality variation" and at times the workers were well aware of the importance of the defect on the overall quality of the car. In my view this shows that by providing more human-focused forms of work and thus providing more comprehensive and meaningful work, one cannot prevent human errors to occur. It is this point which distinguishes the Taylorist and Fordist production systems which envisage the worker to function like a machine, and the human centred production system in which the worker is treated more human, including the consequences the human aspect has on the quality of the product.

However, the resulting quality problems encountered at Volvo have to be relativised. Despite the quality variations pointed out above, according to J.D. Power statistics of 1993, Volvo nevertheless ranked first in the list of quality improvements made and for the 940 model (later renamed 740 model) manufactured at Uddevalla, complaints per 100 cars had decreased from 132 to 87 Berggren 1998:340). Within Volvo, "Uddevalla and Kalmar, improved most of all and had a clear lead in comparison to the Gothenburg plant" (ibid.). Whereas Uddevalla headed the quality within Volvo, based on the average number of assembly mistakes made by 42 teams in 1071 cars between August 1991 and October 1992, Engstöm et al. figures show that 40% of all teams were responsible for a mean assembly defect score of between 40 – 49. (Engström, Jonsson, Medbo 1999:214).

In addition to the effect of the humanised production system on quality and efficiency, the fact that workers could organise their work individually without following precise standards also posed a challenge to the role of management at the Uddevalla plant. To place the human being at the centre of the production organisation and management meant a loss of power and control of management (Jürgens 1998a:21). The classical management function was reduced to setting the production programme/schedule (output quantity) and to contribute "expertise to the process" (Hancké and Rubinstein 1995:183). Ellegård goes as far as pointing out that the managements' "power base was being threatened" (Ellegård 1997b:320).

Coriat on the other hand, argued that management was still able to exert pressure on the workers, so that one the one hand, working speed for one set of workers was still set from outside the group, on the other, the group was free to structure the given assembly time (Coriat 1995:31). For example, the "rigid parallel flow" underlying the production scheduling system restricted the groups influence on the planned production sequence, thus preventing the accumulation of the necessary "working-up". For, according to Engström et al., as "the production schedule was planned minute by minute weeks before the manufacturing moment, the human flexibility was therefore not fully utilised" (Engström, Jonsson, Medbo 1999:220).

Moreover, the computerised control system necessary for controlling the flow of cars on the AVG's was not integrated into the system, particularly as "a specific AGV did not recognise what product it carried, nor was it possible to have detailed control over all transports or give priority to the most important transport assignments according to the status of the assembly work" (Engström, Jonsson, Medbo 1999:219). There was no structural congruence between the transport and material handling system and the autonomous work structure within the assembly work shops.

The impression visitors got was that the Volvo plant at Uddevalla rather resembled a cluster of garage shops than a proper factory for automotive assembly (ibid.). According to Jürgens, the impression visitors had was fundamentally counter to the principles of engineering and industrial planning. Instead of transparent, determined processes and clearly defined structures, chaos ruled at first sight. Instead of impressive technology in big assembly halls, the picture rather resembled that of uncoordinated buzzing small workshops (ibid.:22).

To give the main points of this part, the reflective production system at Uddevalla offered an alternative to the traditional system of mass production. Instead of introducing a system of standards intended to regulate and control the work of the individuals, the actors in production performed tasks according to their individual best way. This created a flexible factory which could be adapted to the developing skills of the workforce (Jürgens 1998a:26). In my opinion the key point about the reflective production system is that the intention of humanising work was achieved by the decision not to set standards regulating the work of the actor. Instead of controlling and regulating what and how workers have to perform tasks, as traditionally done through standard routines in the system of mass production, workers at Uddevalla organised and performed tasks themselves. Moreover, instead of following standards regulating the number of tasks workers have to perform, the reflective production system offered workers the possibility to complete the assembly of a car and thus encouraged the creation of holistic and functional tasks.

However, this does not mean that standardisation was not completely abolished at Uddevalla. The material handling system (kits) and the transport system were standardised. To some extent, these standards did curb the well intended freedom workers had over the organisation of their work. For one, the pre-commissioned kits consisted of components already arranged according to the specific tasks of team and laid out in the sequence for assembly. The kits thus somewhat influenced the sequence of tasks workers performed.

Uddevalla did away with two key factors traditionally associated with the alienation of work: short cycle times and highly repetitive work. Instead of setting standards regulating task content and cycle time for individual assembly stations, by training workers to potentially assemble an entire car, the reflective production system then offered the workers the opportunity to decide on the extent of work content and thus their individual cycle time: work was structured and organised around the skills of the worker. Far from causing the alienation of work, this allowed workers to gain a holistic view of their work.

This reflective approach towards production was later applied at Saab Trollhättan. It influenced the introduction of so called modular units at GM and VW, and as I shall come back to later, the Mercedes-Benz plant at Rastatt I.

3.7 The current trend: standardised production systems

The purpose of the final part of this chapter is to give an overview of the current form and functions of standards in production systems in the automotive industry. I shall focus on an analysis of the evolution of this trend and its implications.

The introduction of standardised production systems in the automotive industry today shows a clear trend that companies primarily model their production systems on the Toyota Production System. Insofar it seems that the TPS has evolved as the dominant reference model, the de facto model of standard production systems. This process towards institutionalising the TPS, is rooted in the lean production discussion during the early 1990s.

The MIT study propagated the universal principle of lean production late to be termed lean thinking, as universally applicable principles for the organisation of production systems (Jürgens 2002:6). The current trend of introducing standard production systems represents one approach toward implementing this message of the MIT study and marks a new stage in the evolution of production system.

Whereas during the phase immediately preceding the publication of the MIT study, during the early 1990s, Western managers had flocked to Japan to study the principles of lean production at first hand but remained reluctant as to the adaptation of the Japanese systems, today exactly these principles are being introduced as part of standardised production systems in the automotive industry. Seemingly through the back door, the Toyota Production System as become institutionalised, best practice standard and today represents the reference model for standard production systems of automotive manufacturers in the West.

A key factor driving this process is the need to achieve a competitive position within the world class in order to survive global competition and in a first step during the early 1990s, companies resorted to benchmark studies to examine the claims of the MIT study in detail (Leibfried and McNair 1996:46).

Taking the example of Mercedes-Benz plant Untertürkheim, prompted by the publication of the MIT study, and following their colleagues from other manufacturers, Mercedes-Benz managers flocked to Japan.[23] These so called benchmark trips were organised by McKinsey and Andersen Consulting. Groups consisted of centre managers, controllers, production planners and the heads of the respective production departments. Separate bench mark trips were organised for the union representatives. The benchmark trip was prepared and structured in advance by the consultants. First, the benchmark targets, those Japanese companies to be subject to the benchmark study, were selected. Factors such as product variety, company size and turnover were considered in order to provide a realistic comparison with the respective power train units of Mercedes Benz.

Second, a list of criteria to be examined was drawn up and each member of the team was delegated to examine and analyse one particular item during the visits at the selected Japanese company. The criteria to be examined covered for example,

[23] Account is based on interviews at DaimlerChrysler.

production methods deployed, work organisation, and production layout and space.

Third, during the benchmark trip, team members looked at the selected production sites and conducted their examinations. At the end of each day the teams met and presented and discussed their findings. The results of each team member were combined in one formal paper documenting the benchmark trip. Upon returning to Untertürkheim, these results were compared with those of the individual Mercedes-Benz powertrain units. Overall, the competitive lead of the Japanese companies was affirmed. In the case of the transmissions, the benchmark evaluation of 1992 showed a performance gap which showed that the average production costs of Japanese manufacturers were 30 – 35% lower, than those of Mercedes-Benz. As a direct consequence of these results and the bench mark trips to Japan in the early 1990s, management at Mercedes-Benz decided to introduce a new powertrain units. Also, it was decided to cut the percentage of parts manufactured in-house from 50% to a target level of only 30%. This cut could only be realised with the introduction of new models.

However, Western companies were rather adamant in adopting lean production principles and Japanese production concepts as elements into their own production systems. True, isolated concepts like kanban and Just-in-time were introduced, but the holistic systems approach, such a seen in Monden's description of the Toyota Production System was not adopted. In practice, companies applied a range of production systems, according to Jürgens these consisted of a range of modular solutions determined by different professional disciplines such as planners and engineers, but also due to different work policies and plant agreements (Jürgens 2002:7). These already existing routines had gradually evolved as grown structures, principles, beliefs which coherence and incoherence had been institutionalised behind the backs of the actors, instead of having been subject to organisational ratification (ibid.).

The introduction of explicit, formalised production systems marks a shift away from these local, idiosyncratic solutions and informal experience-based routines: production systems contain a deliberate selection of organisational principles (ibid.) which define processes and responsibilities. They thus represent a system of formalised routines. This aspect deserves particular attention, for it points out a change in the form and function of standardisation: where standards in Taylorism and Fordism served a regulatory function, in the production systems today, the term "standard" denotes a best practice routine, which is a variant of the elements of the Toyota Production System.

Initiated by the discussion about lean production methods, during the 1990s companies have gradually adopted best practice methods such as group work, CIP, TQM, and JIT, all derived from the Toyota Production System.

During recent years however, a number of big manufacturers and suppliers started developing and implementing entire production systems, in which all the above mentioned best practice methods are combined under one roof. Springer refers to these as so-called holistic production systems (Springer 2003:14). Thus for example, DaimlerChrylser (DCPS, DaimlerChrysler Production System), Opel

(QNPS, Quality Network Production System), ContinentalTeves (CTPS, Continental Teves Production System), and Volkswagen, have production systems.

At first glance, this development suggests, that each company has developed its own company-specific production system then. However, when comparing the contents of these various systems, it is evident that they are all derived from the TPS. According to Springer, differences in name tags of production systems suggest differences where in fact, non exist (Spinger 2003:15). He explains the similarity of the various production systems with the reason that the principles and methods of lean production have to be adapted to the particular organisational circumstances and context in order to be accepted (ibid.). Obviously, standard methods and principles derived from the TPS, need a company-specific name label for management and staff to identify with.

To examine the similarity between the systems and to analyse their relation to the TPS, in the following I shall discuss two production systems in detail, first the Ford Production System, and then the Audi Production System.

Similarly to other automotive manufacturers, Ford gradually adapted TPS principles.

Commencing in 1980, Ford had been implementing particular elements of the four cornerstones of its production system. In the wake of the discussion Japanese production methods and quality during the 1980s, at Saarlouis, Ford had already experimented with job enrichment, job enlargement, quality circles and the integration of indirect functions such as quality control. During the 1990s, driven by the effect the MIT-study had on the automotive industry, Ford introduced lean management principles such as Just-in-time. It also developed the "Q101 award", one of the first quality awards developed by an automotive manufacturer for its suppliers and derived from the NASA's Failure Mode Effects Analysis (FMEA) model. Moreover, semi-autonomous group work became enshrined at Saarlouis in the formal factory agreement of 1991 (ibid.:43). This agreement formalises the responsibilities of groups for the achievement of corporate goals such as: fulfilling target production output, Total Productive Maintenance, Total Preventive Maintenance, Quality control, cleanliness and tidiness, assuring adequate material supply, adherence to work place safety regulations, improvement of working conditions and flexibility concerning working hours, tasks and rotation (ibid.).

The formalisation of the FPS occurred towards the end of the 1990s. It was driven by three key developments: the introduction the Ford 2000 programme the globalisation policy of Ford; second, the introduction of ISO 9000 certification systems; third, the growing reliance on suppliers as seen in the setting up of supplier parks such as the 220.000 qm sized supplier part at Saarlouis, where eleven first tier suppliers manufacture and supply their modules and parts just in time and just in sequence directly to the final assembly line (ibid.).

The Ford Production System was created to bring together all individual processes the company has under one roof. These Ford Production Processes are divided into seven categories ranging from Personnel Processes, to Industry, Material, and Material Handling Systems, Process Control, "FTPM (Ford Total Production Maintenance) ", Factory Technology and Quality Systems (ibid.).

Despite the difference in the terminology used, these processes are but variations of the key processes defined in the TPS.

A second example of a standard production system recently introduced is the Audi Production System (APS). Driven by its global expansion, Audi developed and introduced its production system in 1997 (Spanner-Ulmer 2000:59). According to Spanner-Ulmer the intention of the project was to create a holistic concept which would formalised the main production principles of Audi; comprehensive insofar as it is seen as a network of concepts related to production, interplant sturcutes, standardisation and organisation, with the human being at the centre of it. (ibid.). It contains similar TPS elements, as discussed in the case of Ford. However, the connections and causalities between its elements is far more stressed than at Ford.

Thus Audi envisages a close interlink between the nine key elements of its production system, which are: CIP, visual management, Teamwork Problem Solving Processes, Standardised Work, Material Handling Systems, Work Place Organisation, Quality processes, Total Production Maintenance (ibid.: 60). Rather than defining work organisation as function of group work, at Audi, an ergonomically sound and safe working environment, transparency, clearly defined processes, cleanliness and tidiness, quality improvement, to name a few, are attributed to an efficient material flow system. Of further importance in the Audi production system are flexibility concerning production schedules and purchasing (suppliers), and its global strategy, particularly the creation of lean hierarchies in green field plants and the management of the logistic processes, such as for example from and to the Audi TT assembly plant in the Györ/Hungary (ibid.:63-65).

The two examples pointed out above are representatives of the fact that TPS elements have become integrated into production systems of automotive manufacturers: be it the production systems of Opel/GM, VW, Skoda, Renault or Porsche, looking at the content of these production systems, they all contain similar key elements. Be it sub-systems, core elements, basic principles, tools: they cover a set of common production methods derived from the TPS: group/team work, standardisation, quality, just in time and continuous improvement (Jürgens 2002:9) and they represent highly formalised production systems (Jürgens 2002:slide 5).

Furthermore, the MTM in collaboration with REFA proposes the introduction of an all industry encompassing general standardised production system, the so-called holistic production system. It is based partly on this set of TPS standards which has crystallised but it also contains standards which have been already used and propagated in the REFA-methods (Fischer 2002).

The function of this MTM production system is identical to the function of production systems of the automotive industry that is to provide a framework, a system, a toolbox which contains the complete instruments needed in a production system (MTM 2002:2). The instruments it refers to are based on the same set of standards dissected from the TPS: "Work organisation, CIP, Process optimisation, JIT, Quality Management, Standardised work, Robust processes, Leadership/Management, Visual management and in addition health and safety, and environmental protection" (MTM 2002:5).

The variations between these various examples of production systems are twofold. For one, as seen in the case of Audi, they vary as to the degree of integration of methods into one overall system. According to Jürgens, whilst some systems stress the interrelation between its constituent elements, others stress the interrelatedness of its elements.

A second difference between the production systems concerns the issue of standardisation. Along Adler and Cole's argument, some companies stress the significance for organisational learning and the continuous improvement of processes, whereas the issue of standardisation in other production systems is less prominent or is even rejected (ibid.).

Apart from the inherent differences between the focus of their content, there are significant differences regarding how production systems are implemented and what function they play within the company. I shall discuss these aspects in detail with reference to the Chrysler Operating System (COS) and the Mercedes Benz Production System (MPS). Suffice at this stage to point out that the implementation of both the COS and the MPS is based on a top-down cascade system intended to ensure the knowledge management and identification ibid. To control the implementation process and also the continued application of the production system standards, Mercedes, for example specifically developed a production system audit.

In sum, the purpose of this chapter was to present the evolution of production systems in the automotive industry and the form and function of standardisation therein. There are three distinct models of production systems.

Incorporating Taylor's principles of scientific management, mass production represents the first production system because it integrates standards which until then had not been combined into one system of production organisation. Its key components are: technical and process standards, work standards and social standards. Ford extended the form and function of standards as he refined the system of jigs and gauges and introduced new technical standards of entire car components. He also extended standardisation to production processes which thus determined the work places and work content. Refining Taylor's *Principles of Scientific Management*, Ford deployed standards to regulate the sequence and timing of tasks. Thus Taylor's "one best method" approach became best practice in the automotive industry. Under Fordism, the forms and functions of standardisation extended to the social area. Through the inspections of the social department at Ford, living standards were checked and inspected. Worker had to adopt these standards in order to quality for the 5$ day wage.

The second major model of production systems which has evolved over time is the Toyota Production System (TPS). Although it originates from Ford's system of mass production it has introduced distinctly new forms and functions of standardisation. Thus standard operations and the kanban system represent information systems as they provide a medium in which information is transformed, transferred and transported. This process is driven by the continuous improvement process which "creates a powerful learning dynamic and enhances the problem-solving capabilities at the enterprise level" (Kenney and Florida 1988:132). The inclusion of the shop floor know-how and experience plays a key role in the constant refinement of standards (Shimizu 1999). Thus "the centrepiece of the Japanese approach is the recognition that creating new knowledge is not simply a matter of"processing" information. Rather, it depends on tapping the tacit and often highly subjective insights, intuitions, and hunches of individual employees and making those insights available for testing and use by the company as a whole" (Nonaka 1991:24), thus the workers' intellectual capacities are used for the goal of production (Dohse, Jürgens, Malsch 1985). This led Adler and Cole to go as far as considering standardisation as "essential precondition for learning" (ibid.) and they envisage that each worker and each work station represents a "centre of innovation" (ibid.). As the innovative ideas are directly incorporated into standards, workers are able to influence standards. By combining standardisation and the continuous improvement process, organisational learning takes place.

In contrast to the key role standardisation thus plays in the Toyota Production System, the reflective production system of Volvo at Uddevalla deliberately rejects the use of standards to regulate the work of the individual actor on the shop floor. Its intention is to create a human centred production system in which workers have the freedom to organise and perform their own work according to their individual skill level and their own methods of work.

Looking at the current situation in the automotive industry, the introduction of standardised production systems reflects a continuation of the introduction of lean production principles to Western automotive manufacturers with a specific orientation towards the Toyota Production System. This link is evident in the key elements these production systems contain: group work, standardisation, quality, Just-in-time and continuous improvement are core elements current production systems (in more or less the same form) contain. However, these standard production systems are not clones of the Toyota Production System, but differ with regard to the interrelation of their elements and the role standardisation plays.

This industry-wide trend of implementing one specific reference model is has, as mentioned above, been triggered by the MIT study, and the consultancy profession. The target has been the management. This raises the question as to the influence the unions have over the adoption of production systems?

Historically, unions supported standardisation, particularly standards regulating the protection of workers health, working conditions and their acquired rights. During Taylorism, on the one hand, time and motion standards served, that a specific efficiency level was achieved; on the other though, standards protected workers from the pressures existing on the shop floor, specifically from the threat of "speeding up". Conflicts concerning "speed-up" represent a classical cause for strikes in the labour relations in the USA and became subsequently regulated by collective wage agreements.

In Germany, time and motion studies became regulated in the collective bargaining agreements between employers and unions and are thus an issue of codetermination, right of union representatives to voice their opinion concerning company work policy). In order to prepare these union representatives for their role in this decision making process, they underwent the Industrial Engineering training as offered by the REFA and hence learned the methods and work practices of the Industrial Engineers at first hand. The intention to control the standard setting function of the Industrial Engineers (time and motion standards) by both employers and worker representatives, was particularly evident in the industrial nations in the West. Thus the influence of the Industrial Engineer to control and improve speed and standards at work gradually declined. Instead, standardisation, time and motion, and ergonomic standards and became key subject to the conflicts and negotiations between unions and employers. Thus during the 1980s, Industrial Engineering departments were restructured. The advent of lean production thus represented a welcome opportunity for deregulation.

Returning to the main research task, in the following I shall examine the evolution of production systems further by focusing on the specific case of the Mercedes-Benz Production System (MPS).