Integrating Social and Technical Systems:

Lessons from the Auto Industry

By Thomas Kochan & Joel Cutcher Gershenfeld

Introduction

Integrating social and technical systems requires a new way of thinking. Yet, for the majority of the last century the social and technical aspects of work have been artificially divided. Practitioners would routinely segment social and technical issues into separate functional domains, such as engineering and human resources. Even within a domain there would be segmentation – a social domain such as training, for example, would be divided into technical training and “soft” skills training. Scholars developed equally segmented disciplines, organized around technical or social science specialties and sub-specialties.

Periodically over the past fifty years, scholars and practitioners have explored the integration of social and technical systems – noteworthy exceptions to the dominant trend. For example, a group of scholars between the 1950s and 1970s developed what they termed a socio-technical approach to work design (Emery and Trist, 1973). In this module we build in these and other past efforts at integration in order to offer a framework for instruction on the changing nature of work and organizations. Our aim is to describe the nature of social systems with sufficient clarity to facilitate collaboration and action among people trained in both technical and social sciences. We use examples from the auto industry to illustrate the analysis and to motivate classroom simulations set in that context.

Work System Design

One of the most challenging tasks facing engineers is how to integrate technical, political and social dimensions of a complex system. Nowhere is this better illustrated than with respect to the task of designing work systems. Whether the focus is on production, design, service or other work functions, the designing of work systems requires the integration of technical process requirements, complex social interactions and the various political dynamics that arise in any organizational context. For the designers of new work systems, a new, integrative approach is required. As Thomas P. Hughes observed in *Rescuing Prometheus:*

> “System builders preside over technological projects from concept and preliminary design through research, development, and deployment. In order to preside over projects, system builders need to cross-disciplinary and functional boundaries—for example, to become involved in funding

> and political stage setting. Instead of focusing upon individual artifacts, system builders direct their attention to the interfaces, the interconnections, among system components."

The designers of work systems have not, historically, been systems builders. Work system design has its roots, in part in the field of industrial engineering – where the focus was on job design. Beginning with the early research by Fredrick Taylor, the principles of Scientific Management were all aimed at finding the "one best way" to design work to achieve both high levels of productivity and worker satisfaction. This "scientific" approach to job design was the core theory that enabled the rise of mass-production work systems. It remains today a leading example of the dramatic impact that social-science research can have on society.

Yet, the very ideas that were so instrumental to success in the last century are, today, a barrier to future progress. Over the past thirty years, research on human motivation and social interaction has discredited core assumptions inherent in this approach. Moreover, the emergence of a global, knowledge-driven economy demands forms of integrated, systems thinking that are the antithesis of Taylor's segmented, reductionist theory. Instead of breaking jobs down into discrete, component parts, the challenge today is to understand how dynamic sets of tasks interact together. Indeed, Adler (1992) sees the effective integration of technical and human aspects of complex systems is a defining feature of industrial engineering today.

In focusing on work systems, we will be able to build robust theory around the inter-dependence of the technical and social features of work. Further, we anticipate being able to develop practical tools for putting this theory to use in work settings. This close look at the auto industry is designed to outline the elements of such a theory and to illustrate the types of tools and practices that might be used to implement it.

While we focus on work systems, the ideas developed here may apply to a broader set of engineering and management systems. As the quote from Thomas Hughes suggests, the field of Systems Engineering emerged out of recognition of the interdependence among the technical, political, and social dimensions large scale projects such as the SAGE missile defense project of the 1950s and other industry, government, and university projects (Hughes, 1998). Thus, it may be worth considering whether these ideas apply to a broader set of challenges engineers and managers face as well-not just limited to work design.

We use the experiences of the auto industry to illustrate how concepts and practices of work design have evolved over the past two decades. This industry has served as a learning laboratory for both researchers and practitioners as it experimented with alternative ways for improving productivity and quality, and responding to the interests of multiple stakeholders that share power in the industry. Considerable empirical evidence has been generated to date by researchers who have assessed the effects of what are commonly called "knowledge driven" or "high performance" work systems (Walton, 1974; Cutcher-Gershenfeld, et. al., 1998; Appelbaum and Batt, 1994; Ichniowski, Kochan, Levine, Olsen, and Strauss, 1996; Osterman, 2000). In what follows, we outline how the problem gained salience in industry over the past twenty years, review different approaches to addressing it and the evidence for their effects, and then provide an interactive case designed to illustrate how these tools might be used in different industry settings.

The Auto Industry: 1979-Present

In 1979 NBC produced a documentary titled "If Japan can do it, why can't we?" It focused on the growing awareness that Japanese manufacturers, and Japanese automakers in particular, were producing and selling products of higher quality with higher productivity than many of their American competitors. Thus began a decade of soul searching over why this was the case that generated a host of responses aimed at closing the productivity and quality gap. No industry felt this pressure more than autos, and no industry tried more different things or received closer scrutiny from the public and from academics.

General Motors was the first to respond aggressively to the Japanese challenge. Its answer to NBC's question was, yes the U.S. industry could do it too, but in its own way—with heavy investment in the most modern, advanced technology money could buy. Over the decade of the 1980s, GM spent upwards of $50 billion on advanced technologies in its plants. Visitors to some of GM's high technology plants such as its Hamtramck facility in Michigan, or its Wilmington, Delaware plant could see the wizardry and complexity of the automated tracking systems that guided parts to their appropriate spot on the assembly line and the high-tech robots. Too often, however the robots were standing idle, under repair, or in some cases moved off the assembly line for real workers to get the job done the old fashioned way. As a result GM learned a lesson, one that two MIT students would later quantify. The lesson was that you can't simply automate your way to high productivity and quality. At the end of the decade after spending $50 billion, GM was still the highest cost car manufacturer in America.

NUMMI and its Legacy

Why did the investments in technology not pay off? Part of the reason may have been that the automation was premature and poorly designed. It was too rigid to adapt to variations in product specifications and it simply automated inferior production systems and practices. But a set of case studies conducted by a Japanese colleague visiting at MIT at the time suggested a deeper reason. In 1986 Haruo Shimada teamed up with MIT graduate student John Paul MacDuffie and visited the Japanese "transplants" of the Honda, Toyota, and Nissan (auto assembly plants) in the U.S. that had opened in the early 1980s. Their objective was to understand what was different about the production and human resource/labor relations practices of these plants compared to traditional American plants. Their key insight was that the starting assumptions of engineers who built these production systems were fundamentally different.

American engineers saw the hardware features of technology and production systems as separate from their human features. The American engineers' conception was that the human features were sources of unpredictable variance that should be minimized. Japanese production engineers on the other hand viewed technology as embodying both hardware and human features. Shimada used the term "humanware" to describe this approach to technology and borrowed a phrase from another Japanese scholar who saw humans not as a source of error variance but as a force for "giving wisdom to the machines."

Figure 1 illustrates the interdependent technical and social/human dimensions of the production system they saw in these auto plants (Shimada and MacDuffie, 1986). Skills, motivation, and flexibility/adaptability were seen as the three key human features that supported the just in time production and inventory control, in line quality control, and other aspects of the technical components of the production system. In turn, supportive human resource practices dealing with selection, training, job assignment, and labor relations were needed to achieve and sustain the required worker attitudes and behaviors. They suggested that performance of this system was highly dependent on these human dimensions, and thus they describe it as *fragile*, compared to more robust systems that built in a variety of technical or organizational buffers such as inventory, separate inspection, and large repair that made the production process *robust* in the face of human error or some other breakdown in any single step in the supply or manufacturing process.

While Shimada and MacDuffie's case studies provided the initial qualitative understanding of Japanese transplant production and human resource practices, the first hard data showing the results of these systems came from John Krafcik's case study of New United Motors Manufacturing Inc (NUMMI) and his comparisons to other U.S. plants. NUMMI is a joint venture between GM and Toyota that was set up in 1982 to produce compact cars for both companies. Toyota was to manage the new organization in a former GM plant in Fremont, California that had been shut down two years earlier. Fremont had the reputation as one of GM's worst plants in terms of productivity, quality, and labor relations. This was a two-way learning experiment. For Toyota, it was a chance to see if a U.S. workforce and a U.S. supply base could support what was coming to be known as the Toyota Production System (TPS). For GM, it was a chance to learn more about this new production system.

The NUMMI story is so much a part of industrial folklore in the auto industry (Adler, 1992; Levine, 1995; Wilms, 1996) that we need only summarize the punch line here. Within two years of the restart of this plant under Toyota's management, production system, and labor relations, the same union leaders, largely the same workforce, and with the same relatively old technology had become the most productive and highest quality auto producer in the U.S. The data displayed in Figure 2 illustrate this finding. This is a table that was generated by John Krafcik's research at the MIT International Motor Vehicle Research Program for his Master's thesis in 1988. We have used this table numerous times in courses with Senior Executives at MIT, some of whom were from GM or other parts of the auto industry. Showing these data, reinforced the notion that a "picture is worth a thousand words." Time and again executives who were skeptical of the powerful difference high trust, participative, flexible, secure, well trained and properly led workers could make came over to accept the reality. Labor-management relations, when combined with a production system that emphasized quality, flexibility and continuous learning, and integrated technology and human resources, could produce, in the U.S. what Krafcik called "world class manufacturing," what Paul Adler (1992) called a "learning bureaucracy," and what later (accurately, but perhaps unfortunately) was labeled "lean production" (Womack, Jones, and Roos, 1990).

While the NUMMI results were impressive and good for teaching, two questions remained unanswered. First what actually accounted for these differences? Was there some single "silver bullet" feature of the NUMMI design that could be replicated elsewhere with the same results? Or was it the full NUMMI model that mattered, and if

Figure 2-1
NUMMI Compared to other Auto Plants (1986)

	Productivity (hrs/unit)	Quality (defects/100 units)	Automation Level (0:none)
Honda, Ohio	19·2	72·0	77·0
Nissan, Tenn.	24·5	70·0	89·2
NUMMI, Calif.	19·0	69·0	62·8
Toyota, Japan	15·6	63·0	79·6
GM, Mich.	33·7	137·4	100·0
GM, Mass.	34·2	116·5	7·3

Productivity: standardized number of man-hours to weld, paint and assemble a vehicle.
Quality: defects attributable to assembly operations reported in first six months of ownership.
Automation level: robotic applications/production rate, normalized to 100 for highest level in the group.

Source: John Krafcik, "Triumph of a Lean Production System," Sloan Management Review, 1988, Vol. 3, pp. 411-52

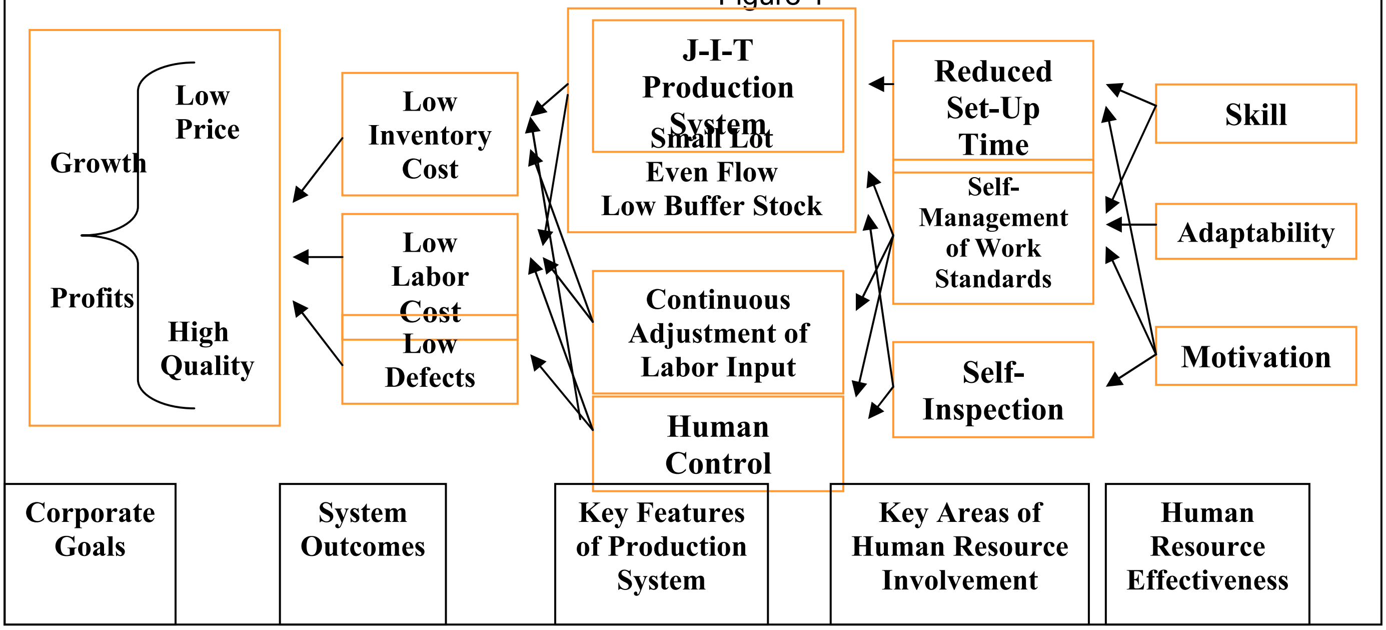
so, what are the key features of the model? Second, to what extent are these results generalizable, either to other auto plants or to other industries? A decade of research has now addressed these questions.

Evidence on High Performance Systems: Integrating Technical and Social Dimensions

John Paul MacDuffie (MacDuffie, 1995; MacDuffie and Pil, 1997) built on the Shimada and MacDuffie case studies and the Krafcik methodology for comparing productivity of assembly plants by conducting an international assembly plant study. They found that indeed the results generalized and that again worldwide, it was not the most automated plants that produced the highest productivity and quality but those that integrated flexible automation with flexible work systems and supportive human resource practices. Moreover, they showed that it was the joint effects of systems that "bundled" together the elements in Figure 1) – both the technical and social/human features that produced these results.

Meanwhile similar evidence for this "bundling" or "system" effects were appearing in studies of work systems and human resource practices in other industries. Joel Cutcher-Gershenfeld had earlier documented this in his study of traditional versus transformed workplace practices in the office products industry (Cutcher-Gershenfeld, 1991). Over the course of the 1990s, similar results were published from studies in the steel, apparel, metalworking, trucking, airline, and semiconductor industries (Ichniowski, Kochan, Levine, Olson, and Strauss, 1996). The terms "high performance work organization" or 'knowledge based" work systems, became the popular labels used to characterize these systems. Their common feature was that the combination of elements outperformed the individual elements.

Figure 1



Source HaruoShimada and John Paul MacDuffie, Industrial Relations and "Humanware" (Slaon School of Management Work Paper, September, 1986)

More recently, the same basic set of results has begun to appear in studies of the information technology and work systems. For most of the 1990s, an apparent productivity paradox puzzled researchers and frustrated managers who were investing large sums in IT systems only to achieve disappointing results. MIT economist Robert Solow captured this frustration with his often quoted statement that "you can see information technology everywhere but in the productivity numbers." Recent work by Bresnahan, Brynjollfson, and Hitt (1999) have begun to unpack the paradox, producing results that replicate the earlier findings with manufacturing technologies and work practices. They find that high productivity is a function of the joint investments of IT with innovations in work systems and human resource practices.

So the bottom line of this line of research suggests that by attending to these micro social and human resource aspects of work systems and integrating them with the appropriate technical or hardware tools and resources, "world class" levels of productivity and quality can be achieved.

The Auto Industry Today: Consensus on Concept; Work to do on Implementation

Looking back on the work reviewed above suggests that the past two decades have been an impressive era for organizational learning and transformative thinking and organizational learning. The hard empirical evidence reviewed here, plus the practical experiences of managers across the auto industry produced a remarkable consensus: Lean manufacturing is the model for world class manufacturing. Each of the major companies has now articulated its own variant of a lean manufacturing strategy. Ford, for example calls its own system the "Ford Production System. It has eleven interrelated components but rests on the same foundation principles of the other lean models and high performance work system models.

Gaining this type of widespread consensus in an industry is quite unusual. Diffusion of these principles undoubtedly accounts for some, if not most, of the general improvements in productivity and quality experienced in the industry and for the ability of American producers in particular to close some of the performance gaps with their Japanese competitors. Yet, significant variation in performance outcomes continues to be observed, both across companies, and across plants and product lines within the different companies. Thus, the challenge now has turned to the task of implementing these new technical and social systems' concepts.

The Organizational and Institutional Components of Work Systems

So is the story now complete? In some traditional approaches to industrial engineering the answer would be yes and manufacturing engineers and managers would be trained to go into plants and check off the different social and technical features discussed above, adapt their features to the idiosyncratic elements of the particular environment, and attempt to implement these practices. Indeed, a great deal of such behavior can be found in industry today, including in the auto industry. But most such efforts fail in implementation, or if implemented, fail to achieve the high-level performance results expected. MacDuffie and Pil,(1997), have shown, for example that the later adopters of this production and human resource practices did not reach the same performance levels as the earlier adopters. Moreover, they and others (Kochan, Lansbury, and MacDuffie, 1997) have shown that despite the efficiency claims of lean production, it has not spread to all parts of the global auto industry nor are its principles applied in the same fashion in all settings where they are used.

In a study of the cross-cultural diffusion of knowledge-driven work systems, Cutcher-Gershenfeld and other members of that research team found that diffusion was not successful when it was done on a piecemeal basis or when all the features of a work system were imposed at once. Only a negotiated process of diffusion was effective – where all the stakeholders were able to learn from the existing system, but adapt it to match the unique characteristics of the new location (Cutcher-Gershenfeld, et. al., 1998). In other words, the process for developing or adapting the new work system is instrumental to its success.

To understand the variations in work systems, we need to consider the broader organizational and institutional features that influence the design of work and employment relationships. Particularly, we need to consider where work systems fit in the strategic objectives of the key stakeholders that share an interest in them and the political and cultural contexts in which work takes place and build these into our theory and tools of work design. In short we propose that these organizational and institutional features are also critical elements in work systems.

Strategic Considerations

The above discussion assumes that the task of work system design is to optimize productivity and quality. Clearly these are critical performance criteria. But work is a central activity and concern for multiple stakeholders and each will bring its own interests and priorities to bear on how work is designed and how work is actually done. Broadly speaking, any work system must effectively address the interests of at least four major stakeholders – customers, shareholders, the workforce and society. Work systems are, after all, only one component of a broader set of strategies that compete for resources and priority within complex organizations. Gaining and maintaining top management support for investing in the development and sustainment of these work systems is not guaranteed. Indeed, within organizations competition for such resources and managerial priorities and attention is itself a contested political process (Thomas, 1994).

The strategic challenge is particularly vivid in the case of the Fiero car – a product of General Motors. In the mid 1980s, this car pioneered a new market segment for small, affordable sports cars. It quickly drew competition from the Toyota MR2 and the Mazda Miata. In the face of declining market share, corporate infighting (with Firebird, for example, over increasing Fiero performance), and other factors, the product was cancelled. In field interviews that were happen to have been conducted on the factory floor on the day the product cancellation was announced, the response was uniform. The anger and disappointment was less about the product being cancelled than about the lack of value placed on the capability of the workforce. People commented that they had an effective team-based work system, they had mastered the use of composite plastics in auto bodies (which had never been done before), they had hourly workers making daily customer contact phone calls, and they understood the concept of continuous improvement. The dominant feeling was anger that a new product wasn't awarded so as to keep the workforce together – placing a value on the investment in capability that had been made (on the part of the corporation, the union and the individuals). Simply put, the Fiero story illustrates a massive blind-spot in strategic decision-making when it comes to valuing work system capability.

The pattern of diffusion of lean manufacturing and high performance work systems in the U.S. auto industry illustrates this point. The most rapid adoption of high performance work systems in the U.S. auto industry occurred in the late 1980s and then slowed to a halt in the 1990s. The NUMMI data, substantial gaps in quality performance, the recognized threat of Japanese competition, and the growing attention to quality principles led to significant diffusion in the earlier period. But by the early 1990s, development of new hot selling products became the dominant profit producer for U.S. auto companies. Attention and priorities shifted to getting these products to market quickly. For Chrysler it was the minivan. For Ford and GM it was the growth in demand for trucks and Sport Utility Vehicles that became the profit generators and gained management attention and resources. Resources (both financial and managerial support) for innovation in manufacturing work systems primarily focused on the products themselves, though there was also an upsurge of interest in product design innovations, such as "platform design" and "concurrent design" systems.

Political Issues: The Multiple Stakeholders, their Interests, and Power

Managers are not the only interest group that cares about how work is organized. Nor do they have the power to always implement work systems unilaterally. This was the fallacy of Scientific Management, that the conception of how to do the work could be separated from the people who actually do it. Just setting up incentives to gain conformance with the engineer's conception of how the work should be done assumed that all the relevant knowledge resided with the expert. As we know, it's not that simple. Any complex system involves multiple parties, each of which approaches the task with their own interests in mind. Whether these interests are all aligned or whether there are tradeoffs is an empirical question (and perhaps can be influenced by the design), one that needs to be explored in the design, testing and implementation, on on-going deployment phases. Moreover, all those involved do not possess the same amount of power to press their interests or priorities. Thus, all phases of the design, implementation and on-going deployment of any complex system are influenced by these political features and must be taken into account. Again the auto industry provides a vivid illustration of this point.

Consider Saturn. Saturn is a division of GM that was created with two objectives in mind: to build small cars profitably in the U.S. and to provide jobs for U.S. workers. It was motivated by the realization that GM could not build small cars profitably with its traditional organizational structures and labor relations practices. Consequently, in 1983 GM and the United Auto Workers (UAW) created a joint study committee to take a clean sheet approach to both organization design and labor relations. Out of this "Committee of 99" as it was known came a design that called for a team-based organization in which workers and their UAW representatives would share decision-making with management at all levels and across all functions of the organization. The work organization system was based on a set of 30 work unit functions that each team would perform, many of which traditionally had been carried out by supervisors or middle managers in traditional GM plants.

While the Saturn system benchmarked NUMMI and Toyota, the system was based on very different assumptions than what came to be known as "lean production." High levels of power and authority were vested in the teams, and a partnership structure was employed instead of a traditional management hierarchy. Saturn's task and job design represent a synthesis of a European socio-technical approach with the lean production system. Saturn teams have greater decision-making autonomy than lean production teams.

While most lean production plans rely on job cycles of about sixty seconds cycle times at Saturn vary considerably and can extend up to six minutes as moving platforms carry workers along the assembly line while they perform their designated operations. In fact, there were predictable tensions as the principles of lean manufacturing impacted on the Saturn system in form of reduced in-process inventory and increased interdependency among teams. The autonomy enjoyed by teams was eroded and concern over GM's commitment to this model heightened. This original design has recently been under review by a joint task force and is likely to revise the team structures to move in the direction of lean production teams in an effort to reduce costs and improve quality and cross team coordination.

Saturn's work system and organizational design would not have been chosen if workers and union representatives had not been part of the original design team or the partnership structure and process that implemented and managed the operations. Worker interests were built into the system right from the earliest stages of the design process and the goals of the system reflected the interests of the multiple stakeholders involved. This continues to be the case, as Saturn now moves into its second generation of products and organizational history (Rubinstein and Kochan, 2001).

Cultural Features

Culture is used in many ways in the social sciences, often in such a general way so as to loose any analytical meaning or value. Yet to ignore the cultural contexts in which a system is embedded dooms any efforts to change it. We adopt a very specific definition of culture here to capture the basic underlying assumptions and values that influence the meanings parties attach to a phenomenon, in this case, to work systems (Schein, 1985; Ancona, Kochan, Scully, VanMaanen, and Westney, 1999). While the term is popularly used to reflect cross national variations (Hofstade, 1980) organization theorists have long recognized that the culture of any given work setting also reflects the unique traditions and norms built up in different organizations (Schein, 1985) and sub-organizational units or occupations (VanMaanen and Barley, 1984).

The importance of culture can be illustrated by stepping back and reviewing the evolution of this term "socio-technical" systems and then looking again at current examples in the auto industry. The term "socio-technical" work systems grew out of a series of experiments conducted in Scandinavia and Britain in the 1950s at the Tavistock Research Institute. These experiments were also designed to find ways to organize and design work systems to maximize satisfaction and productivity. The most famous experiments took place in the British coal mining industry. The primary defining feature of this effort came to be the use of semi-autonomous or autonomous work groups. Volvo's Kalmar and Udevalla plants in Sweden were designed around these principles as were several of the plants in the U.S. which gave rise to the concept of "high commitment work systems" (Walton, 1974).

Subsequent research on the nature and diffusion of Japanese work systems in the U.S. highlighted a distinction between what can be termed "lean" teams and "socio-tech" teams. The lean model generally involves smaller, more interdependent teams – with few social or technical buffers. By contrast, socio-tech teams are generally larger and more autonomous, which is enabled by both social and technical (Cutcher-Gershenfeld et al, 1998). Figure 3 summarizes the differences this group observed in plants that adopted lean production teams and those that adopted socio-technical system teams.

Figure 3
A COMPARISON OF THREE TYPES OF TEAM SYSTEMS

	Lean Production Teams	Socio-Technical Systems Teams	Off-Line Teams
Origins:	Japan (Toyota Pull System, 1960s)	Scandinavia (Volvo Kalmar, 1970s) and England (coal mines, 1940s)	U.S. (Harmon and GM/UAW QWL groups, 1970s) and Japan (Quality Circles, 1980s)
System Optimizes:	Continuous improvement in work operations	Mix of social and technical sub-systems	Ad hoc problem solving
Expected Yield:	Systematic gains in quality and productivity	Increased worker commitment and targeted gains in quality and safety	Increased worker commitment and reactive response to quality problems

Success Constrained by:	High expectations of team autonomy; Low labor/management support for continuous improvement	High levels of team interdependence; Limited resources for technical redesign	Separation from daily operations
Typically Found in:	Assembly operations (high interdependency among teams)	Continuous production operations (high autonomy among teams)	Broad range of workplaces
Leadership:	Depends on strong team leader	Depends on self-managing group	Depends on group facilitator
Membership:	Common work area	Common work area	May draw on multiple work areas
Organization Structure:	Core building block	Core building block	Adjunct to the structure
Links to Other Teams:	Tightly linked to internal customers and suppliers	Tightly linked across shifts; loosely linked with other teams	Little or no links among teams

Source: Knowledge-Driven Work: Unexpected Lessons from Japanese and United States Work Practices, Cutcher-Gershenfeld, et. al., 1998.

A second example is the difference between teams in Korea and Germany. The plants surveyed in both of these countries in the second round of the international assembly plant survey reported very high levels of team activity. Yet a closer look at actual work processes in Korean and German plants showed few similarities in actual processes (MacDuffie and Pil, 1997). Korean work teams continue to reflect the strong authoritarian managerial culture and management style that is embedded deeply in Korean society whereas the types of teams found in German auto plants vary depending on the extent to which the group work model favored by the German Metalworkers Union IG Metal or the more lean manufacturing model adapted by managers experienced in the NUMMI system (Jurgens, 1997; Roth, 1997).

All these examples are simply meant to illustrate the point that work systems in general, and in this case, teamwork specifically, mean different things in different cultural settings and reflect the accumulated experiences and power relationships that characterize each setting. As such they need to be viewed as part of the system itself. Failure to understand the values, traditions, and meanings that underlie these features dooms efforts to change them or to introduce new system features into these settings.

Work , Time, and Family Connections

A final feature of the culture of work systems needs to address are often implicit or unstated assumptions that underlie work design. This is best illustrated by recent research on work and family issues (Bailyn, et al, 1999; Williams, 2000). In a recent project Lotte Bailyn and her research team worked with several engineering and sales work groups to identify options for altering how they worked in way that would both meet their project performance objectives and reduce the stresses employees were experiencing because of long hours. By questioning the implicit assumption that there is a linear relationship between hours at work and productivity, the parties identified ways to reorganize their work and time allocations in ways that achieved their objectives.

This assumption is engrained in the design of not only the work systems found in these units but in many professions. It is especially prominent in the training and early stages of careers in law, medicine, consulting, and research-oriented universities. Recognition of the effects that this feature has on women, has led Joan Williams to argue that this implicit assumption about the "ideal worker" (one available for long hours and full time commitment to work and career over all stages of one's working life) represents a subtle but systematic form of discrimination. Holding to this assumption leads to work designs that reinforce this image and make it a self-fulfilling prophecy.

Is this assumption still viable today given the diverse make up of the work force and the increased number of hours that households are contributing the paid labor force? Whether work can or will need to be designed to accommodate more diverse life styles, family and personal responsibilities, and technological possibilities is an open question that goes well beyond the standard manufacturing environment. Work systems intersect with other institutions and social systems such as family life, community concerns, environmental concerns, etc. Thus it is important to treat work design as an open system subject to influence by a variety of factors that may need to be incorporated explicitly into the design process.

In summary, work systems have both hardware -- technical features -- and a set of social features that reflect micro elements of human and work group motivation, educational and skills, and the sub-system elements that make up human resource or employment systems. In addition work systems are influenced by and a part of the broader strategic, political, and cultural features of the organizations and institutional settings in which they are embedded. Ultimately any core theory of engineering systems must attend to the social and technical dimensions of a system, which are both distinct and interdependent.

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