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The ills of multi-person workplaces—Reflecting negatively on quality and employee well-being: A cellular fix

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ABSTRACT
Many workplaces involving multi-person operations and jobs are flawed, such that product or service quality and health and safety of job-holders are compromised. These include work in which each jobholder performs the same task—a "gang" configuration—and certain flow-line modes with operators so separated as to allow little understanding of quality and process flow. Both impinge negatively on process control, obscuring error and causes, and inviting finger-pointing. A theme is that product/service quality and job-holder well-being are close partners, but often, in multi-person workplaces, does not function as such. The article advises solutions centering on multi-faceted advantages encompassed by cellular workplace design. This entails revisions in instructional matter, field practices, and theoretical grounding of relevant professions; suggests potential interventions by affected regulatory agencies; and suggests further research opportunities of an integrative, cross-functional nature, with cellular management as fulcrum. Examples include HR and jobholder issues in various workplace contexts; internal and downstream quality, flexibility, and cost indicators; and with various product types and productive equipment configurations. Such research opportunities are the more salient in that the body of knowledge in the realm of cellular management has grown little in recent years and seems to call for rejuvenation and fresh research approaches.

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Introduction

Many multi-person operations, whether in manufacturing (a factory) or services (processing documents, human customers, or information), are plagued by excessive defects/reworks and/or product-safety risk, along with damage to physical and mental wellness of the jobholders. Two defective modes are singled out: (a) work in which multiple operators are grouped together, each to do the same task set, such groups referred to as *gangs*; and (b) work in which operators in two-or-more-person processing chains [e.g., *sequential manufacturing* (Pulakanam 2011)] are set up and managed such as to afford little knowledge of product and process quality, with consequent adverse impacts. Both modes entail undue repetition, motion rigidities and job boredom, with resultant weakened awareness and attention to process and product quality—a degraded chain of responsibility—along with malign effects on health and safety of the job-holders. (Certain other unsuitable configurations, beyond the scope of this article, are briefly mentioned as asides.) Relevant to these matters are studies (Pagell, Veltri, and Johnston 2016) offering plentiful "evidence that worker health and safety are a foundation of managing manufacturing facilities that are globally competitive." In its emphasis on linkages between quality management and various aspects of employee well-being, this article is taking more of a Big-Q (than little q) approach to quality management—this dichotomy identified long ago by Joseph M. Juran (West and Cianfrani 2018).

This article advises clear-cut and definitive corrective measures centering on a broadly-used and well-tested alternative to the defective configurations, namely, cellular management (CM), with inclusion of systematic multi-skilling and job rotation. When done right, the cellular mode reduces and/or eliminates flaws, raises product quality, adds functionality, and elevates job-holder safety and physical and mental well-being (Hyer and Wemmerlöv 2002; Procter,

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Hassard, and Rowlinson 1994). Is CM, as with so many other process-improvement and/or management initiatives, subject to a pattern of high, then waning enthusiasm? Hyer and Brown (2003, 29), having observed “several instances where organizations move to cells and then back to a functional arrangement,” coined an apt term for it: “functional drift.” Looking at possible CM fallibility from another angle, Johnson and Wemmerlöv (2004) ask, “Why does cell implementation stop?” As to all this, the authors of this article draw broad insights from their extensive years of research on and working on-site with manufacturers and service entities in their efforts to master CM precepts.

> Note on the literature: It may be observed that the certain of the key literature reviewed in this article tends to be seminal in nature, rather than geared to recent-year issues and advances. That is largely because a centerpiece concept, cellular management, had been widely researched in earlier decades, but has—rather clearly—fallen out of favor in the research community. A desired by-product of this research is that of spurring renewed interest, in light of the quality and jobholder well-being issues introduced herein.

In its joining of seemingly disparate concepts and practices—quality, cellular management, process improvement, empowerment/participation, ergonomics/human factors—the research encompassed by this article is intended to contribute to organization theory and strategic management of the enterprise. In that, it follows the lead of various other researchers (Burgess-Limerick 2018; Eklund 1998; Julien and Tsoni 2013; Vicencio-Ortiz and Kolarik 2012; Zhang, Linderman, and Schroeder 2014).

For the most part the article presents examples at a restricted level of analysis, but which are readily generalizable to larger-scale operations. In following sections, the article intertwines the two primary aims: quality-based competitiveness and jobholder well-being. The next section, in expounding on commonplace weak links in multi-person workplaces, introduces a simple example in the area of food production.

Problematic chains of responsibility and their correction

Any error made at any step in a multi-person operation can be, and often is, masked, such that the error is passed onward, becoming manifest (if at all) at a following process. The later an error’s discovery, the less likely its source is identifiable—a prerequisite to its correction: the cold audit-trail phenomenon (Schonberger 2012). To counter this likelihood, best practice calls for high-quality process analysis/engineering to establish, certify, and document best methods, as specifications for thorough training and continuing refresher updates. That widely accepted norm is good practice, but is insufficient.

Multi-skilling and job rotation

Most every employee wants to do high-quality work that is personally fulfilling. But quality and gratification are difficult to maintain in:

a. jumbled work places where there is no (or just sporadic) consecutive work flow and therefore no (or a broken) chain of responsibility [this term a modification of Groocock’s (1986) similar term, “chain of quality”].[1]
b. a work sequence employing two or more operators in which each knows and understands only his/her own job.

In both cases, job-holders’ narrow perspective translates into inability to know what constitutes high-quality work in their own jobs, and to put it into practice—a work life characterized by frustrations, doubts, and, sometimes, fears (Schonberger 2018). This applies when the jobholders are co-located, and even more so in a work sequence in which the flow traverses among physically dispersed operators, as in a shop-to-shop or office-to-office configuration: the out-of-sight, out-of-mind phenomenon. In these contexts quality obtains in the least cost-efficient way: “inspected-in” rather than “built-in.” (Deming, quoting Harold F. Dodge, said, “You can not inspect quality into a product”: Hunter 2012). Moreover, these configurations are havens for the “blame game,” also referred to as “buck-passing” (*Wikipedia* n.d. a): When errors and defects are discovered, each entity in the flow can, vocally or implicitly, deny fault, suggesting one or more others to be the cause (Archer 2020; Ronnie 2020).

Coping with such conditions of limited knowledge of the process-to-process flows calls for multi-skilling (the multi-skilled or multi-functional employee) and frequent job rotation (Hackman et al. 1975; Ortega 2001; Parker and Hall 1998), which is often accompanied or enabled by reductions in job classifications

[1]This use of chain of responsibility lies in its application to quality management, and should not be confused with its usage in information system design where it is generally referred to as “chain-of-responsibility *pattern*.”

Table 1. Flow management and related terminology.

Various authors have suggested that the terms, lean—and its seminal predecessor, just-in-time (JIT)—have become so cluttered with offshoot concepts and definitions (e.g., from consultants in efforts to distinguish their "special" expertise from those of other consultants) as to render those terms as problematic (Holmemo, Rolfsen, and Ingvaldsen 2018). Many are offering *flow management* as an appropriate alternate term (see, e.g., Schonberger 2019a).

(i.e., the various jobs formally specified by H.R. for training and pay purposes)—that being a bedrock practice among companies that engage in just-in-time/lean production (Hall 1987, 113–4; Nicholas 2018, 326). The alternate term, cross-training, has long been in wide use in manufacturing (Harmon and Peterson 1990; Hopp and Spearman 1996; Suri 1998; Suzaki 1993, 165) and also in services (Gang, Field, and Davis 2017) but is largely avoided herein because "cross training" has become widely used quite differently in the context of athletics training/conditioning. The multi-skilling concept is akin to the life role of worker bees—as is colorfully explained in Bittel (2020, 77): "Unlike ants, which have specialized roles, every worker bee is capable of doing every job necessary for maintaining the nest."

In Garvin's (1983) oft-cited article on assembly lines—an in-depth study of a Japanese and an American manufacturer of room air conditioners—he found that training new operators at the Japanese plant took about six months because "they were first trained *on all jobs* on the line." Missing in the report: Garvin did not say whether that extensive initial training had been carried forward as "systematic cross-training and job rotation" (Wang 2015) in the ongoing workplace.

In manufacturing, of companies that have embraced total quality and flow-management principles (see Table 1 on the rise of flow terminology), many choose to implement multi-skilling as an ongoing requirement (see Suri 1998, 96–97, 123–6, 351, 477). Many, as well, have incentivized such versatility in the form of skill-based pay (or pay for skills) (Flynn, Blair, and Walters 1994; Murray and Gerhart 1998; Orsburn et al. 1990, 182–94; Zingheim and Schuster 2000, 107–8). In a rather randomly-selected example (of a great many from the authors' files), Delphi Saginaw Steering Systems, Saginaw, MI, in converting 100-person assembly lines to multiple, compact manufacturing cells, cut job classifications from 120 to 5 and adopted pay for knowledge; contributing to its receiving *Industry Week's* 1999 Best Plant award (Stevens 1999).

Commonly, multi-skilling is accompanied by a versatility matrix on display in the production area (Nicholas 2018, 303–4), proclaiming, for each person, yes-no certification or degree of mastery in key tasks and responsibilities. Multi-skilling so displayed tends to elicit motivational pride and respect: Those who become qualified in many of the tasks/responsibilities are looked up to, possibly as informal team leader or formally designated trainer or lead person, and ultimately perhaps as a candidate for a supervisory position. Without frequent job rotation (Hsieh and Chao 2004), multi-skilling is weakened: People forget or muddle what they had learned in earlier multi-skilling, or they are current on today's tasks but not the changing job specifications that ride on continuous process improvement and product/model changes.

The case for multi-skilling is frequently voiced as a key ingredient in achieving organizational flexibility in the face of increasingly turbulent demand patterns (Christensen and Rymaszewska 2016; Heine et al. 2016; Peters and Blomme 2019; Upton 1994). Smith, Gilmer, and Stockdale (2019, 557) observe that "Firms use flexible work arrangements (FWAs) to attract, retain, and satisfy human resource capital, while workers use them to manage work and nonwork demands to reduce stress and conflict." As Kossek, Thompson, and Lautsch (2015, 5) put it, "… implementing flexibility must not be treated as an accommodation [but as] broader systemic organizational change [empowering of] individuals and teams." Contrary to assertions about needs for multi-skilling, however, there is a long-standing viewpoint that, in our increasingly high-tech world, new equipment and automation will result in *less* need for skilled people, a phenomenon referred to as tech-driven "de-skilling." Such reasoning was roundly debunked by Adler (1986); and supported by empirical research of Khurana (1999), who said, "… contrary to the traditional view, successful shop-floor strategies for complex processes emphasize upgrading worker skills rather than downgrading them."

An alternate argument is that highly automated equipment can and often does elevate fixed costs and reduce product-to-product flexibility. Metternich, Bechtloff, and Seifermann (2013), in reference to machining, present research showing advantages of using low-cost, "right-sized" milling equipment, saying, "Cellular Manufacturing can be a lean and flexible alternative to done-in-one … complex, highly automated equipment." They explain that if customer demand decreases in a given machining cell

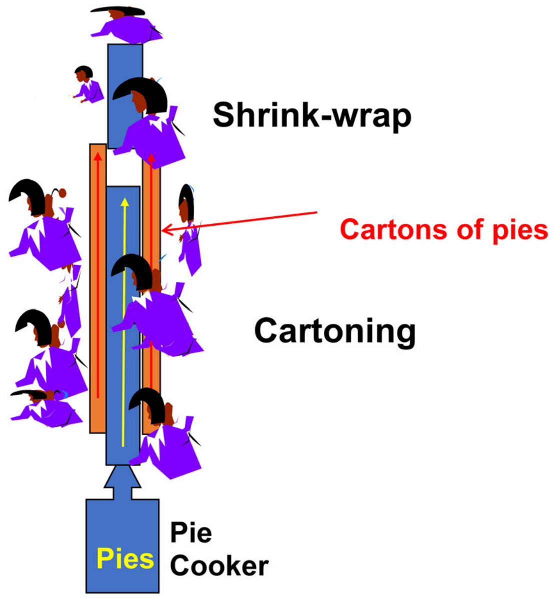

Figure 1. Packing small food items.

configuration, "a machine tool can be removed from the machining cell to be used in another" cell or line … and with "an optimum interaction between each single machine tool and the operator(s)."

Degrading product quality and job quality—food-processing example

Multi-person work of a repetitive nature can take the form of an operator-to-operator or hand-to-hand configuration as in a bucket brigade putting out a fire—a strong responsibility chain. Or, alternatively (case *a* from the section on Multi-skilling and job rotation), a configuration in which the flow is jumbled, such as a gang of stevedores unloading ships, or a gang of packers, each separately grabbing items from a conveyor, putting them into a pack, and pushing them onward to the next process. The schematic in Figure 1 is a simple example of the latter, in which a pick-and-pack operation is arranged into three stages with a total of eleven packers processing small pies as they emerge from a pie-cooker.[2]

- The first stage (first from the bottom in the photo) has six packers, three on each side, in which each packer reaches to the power-driven central conveyor, grabs a few food items (call them "pies"), machine-made in the prior stage and puts them into a small paper carton on the nearest of the two narrow-width powered carton conveyors fronting each person's body; the tallish white devices in the foreground are carton feeders.
- The two carton conveyors move the cartons to the second stage: two handlers, one on either side and at the end of the conveyors, who hand-carry one or more cartons at a time to the third stage.
- In the third stage, about two steps away and topmost in the photo, each of three persons packs a set number of small cartons into larger boxes, which go to shipping, an operation not in view.

The three stages define three "gangs," that mode of work having been described (Schonberger 1990, 8, 54–5) as "… formed to dig, pick fruit, stuff envelopes, gather refuse from roadways, dip candy, sort materials going down conveyors, and perform gang assembly." With gangs—as distinguished from *teams*—each person within an operational stage is independent of the others. Errors are sure to occur during processing, such as, in our example, damage to a pie or a container, poorly placed pies or wrong-quantity fill of a carton, or germs from an unsanitary glove or a sneeze, cough, or other contaminants upon the pies. Other errors would arise as defective incoming materials, such as an under-filled or badly-formed pie or a soiled or dented incoming container. Whether the error occurs prior to or within these operations, in the confusion and hurry of production a person making or noticing the error would have little time to call it out, put it aside, or act to correct it. So the error passes by, a hit to product quality—a problem endemic, especially to the packaged food sector (Schonberger 2019b), given the high susceptibility of foods to contamination.

During the Covid-19 pandemic the news media shed considerable light on these kinds of issues, notably in stories about meat-packing and poultry-processing plants and their propensity to be havens for the coronavirus; one report states that "more than 17,300 meat and poultry processing workers in 29 [U.S.] states were infected and 91 died (Binge and Newman 2020). However, that industry had been singled out long before for both product quality issues (Pulakanam 2011) and barely tolerable working conditions (Charlotte Observer 2013; Conover 2013; Downs 2013; Powell 2010).

> Upshot: *This gang assembly mode of manufacture, with its high probability of passing defective product—and potentially dangerous-to-consumers contamination— onward along distribution channels to final using customers, should be seen as an aversive*

[2]This schematic is identical in form to a photo that originated at Bama Cos. Inc., 2004 winner of the Malcolm Baldridge National Quality Award. It is not known if the pick-and-pack lines of Figure 1 had been visited by the Baldridge examiners, or if so, whether they had seen the configuration as defective.

> *mode of production; and more than that, notably in the critical foods, pharmaceuticals, cosmetics, and medical devices sector, seen as intolerable. Given their regulatory powers over these manufacturers, it may be advisable for the U.S. Food and Drug Administration (FDA)—and counterparts in other countries—to designate gang assembly as unacceptable, and treat it as disallowed under its Good Manufacturing Practices (GMPs).* (Note: Governmental regulatory agencies in certain countries besides the U.S. [e.g., Australia, Canada, Ireland, the U.K.] also use the GMP label.).

This might be seen as over-reaction, except that the issue of dubious production configurations is readily fixable—in ways that correct more than "just" product quality: the fix is cellular production, to be discussed shortly. First, let us set gang production aside so as to briefly consider quality and the job-holder in the mode involving person-to-person hand-offs along an assembly line.

Stunted responsibility chains

Jobs in a workplace like that of Figure 1—standing and leaning forward in a pick-and-pack routine that scarcely allows for so much as a half-step—is tortuous: aches and bodily strains are endemic. The work is numbing to mind as well as body: The pick-and-pack cycle, repeating perhaps every 10 seconds, would total some 3,000 repeats per shift. And since six of the eleven packers do exactly the same task (pick and put into carton), job rotation possibilities are few (each group of three may at least change places—positions, not jobs—now and then, perhaps for competency or socialization reasons).

Such degradations to jobholder well-being are found widely among *assembly lines* (Caroly, Coutarel, and Mary-Cheray 2010; McGillivray, Liotta, and Dorow, no date, re the history of assembly lines at Ford). Many, though, are comprised of different jobs, thus allowing for variety gained through multi-skilling and job rotation. At least in the much-ridiculed gang-assembly case of Figure 1, it's standup work. Contemporary flow/lean/JIT concepts call for avoiding sit-down manual labor—no chairs (with some exceptions, e.g., microscope work; though not with the newer digital microscopes: Bellinger 2020)—because sitting for a whole shift immobilizes skeletal-muscular structures, from backs up through necks. The literature of ergonomic engineering (Helander 2006; Sanders & McCormick 1993) is replete with advanced expertise in dealing with the bodily and mental harm engendered by jobs that severely restrict movement and are plagued by highly repetitive motion patterns (Baio 1998)—including the special example of the electronic office (Franchi and Fleck 1994). Further, studies by ergonomist Julia Abate (in Weber 2009), contrast *static standing* in which jobs do not allow steps—the case in Figure 1—vs. *dynamic standing*: operators taking steps, which "helps distribute more blood flow … to the muscles."

> Corrective action: *Given the extensive body of ergonomic knowledge as well as the contentions of this article on untenable job designs, it may be advisable for the U.S. Occupational Safety and Health Administration (OSHA), and the U.S. National Institute for Occupational Safety and Health (NIOSH)—and counterpart agencies in other countries—to establish, in their workplace assessment criteria, systematic policies for identifying those ills and treating them as unacceptably injurious to employee health and safety.* (Note: Whereas the mission of OSHA, part of the U.S. Department of Labor, is regulatory—visits to and critical assessments of organizational workplaces and enforcement of standards—that of NIOSH is "conducting research and making recommendations for the prevention of work-related injury and illness" [Wikipedia n.d. b].)

As with the earlier segment on gang assembly and the FDA such advisory to OSHA might be seen as over-reaction, except that the indefensible job designs are readily fixable—by following best practices in cellular management of the work, including attention to ergonomics.

Cells: beneficial effects on quality in league with workplace health and safety

In enhancing employee health and safety, and with it, raising process quality consciousness and responsibility, the cellular mode has both avoidance and additive features. Cells avoid highly repetitive jobs by dispersing the work elements. They add variety not only of production tasks but, often, "tasks previously performed by staff, such as inspection, basic preventive maintenance and repair, and job prioritizing and dispatching" (Nichols 2018, 308). Following is a non-manufacturing example.

Processing requisitions and invoices

Consider three office departments—one of buyers; another, invoice processors; and the third, payables clerks. To go cellular, three persons, one from each department, co-locate, thus to make up three cells of a buyer, an invoice processor, and an accounts-payables clerk. Effects: Payables clerks no longer work all day on stacks of invoices forwarded once or twice daily from invoicing, and invoicing persons no longer on stacks of purchase orders from buyers (such mode known pejoratively as *batch-and-queue* processing, Wang 2015). Rather, they are physically moved so as to form into three tight clusters, each in a single-piece flow of documents, catching and fixing errors and working on questionable items as they go—a strong responsibility chain with a compressed audit trail. Further, with three separate cells, each may be dedicated to its own customer family, welcoming to the customer as a single point of contact and in that it reduces mix-ups and instances of rework.[3]

In this format each cell-team member readily learns the skills of the others: Multi-skilling is natural, no prodding necessary [multi-skilling as applied to professionals (Ledfor 1995), as in this example, has been labeled (Schonberger 2008, 103) as *cross-careering*]. This close-together cellular relationship avoids boredom-induced mistakes and cycles of delayed discovery and rework; and it imparts whole-process expertise that does not obtain in a functional department; the multi-skilled/cross-careered employees become a human resource of greater value to the employer, and to themselves. Moreover, the acquisition of that depth of process knowledge, with heightened responsibility and recognition, offers mental health benefits—the realm of cognitive ergonomics.

> This service application of cells is one of processing information. Many other service process types should similarly be suited to such shifting from functional silos to cells. Bicheno and Holweg (2016, 313–7) offer a thoughtful seven-category, lean-management-themed explication of high-potential service operational contexts, each with its own reference list.

Cellular office at Microsoft

The example of forming a cell by co-locating a buyer, invoice processer, and payables clerk is roughly based on a real case (Schonberger 1996, 23, 28). Microsoft had been buying, from many personal-computer manufacturers, high volumes of PCs that the company needed in order to test new software routines. This could involve hundreds of requisitions, purchase orders, and shipping and receiving documents in play, batch-processed from one functional office to another—taking so long that Microsoft was eligible for but not garnering quantity discounts. Solution: It pulled a few people from the offices and moved them to the receiving building, forming a PC-dedicated cell team of buyer, receiving, and accounts payable. (See, also, a cellular example in a retail department-store setting: Harmon 1996, 27–8.) Microsoft's centralized purchasing and payables staffs remained in the usual separable functional offices for processing high volumes and changing mixes of purchased items.

> *Limitation: This article omits discussion of a particularly odious but globally widespread production mode—one exemplified by the cut-and-sew sector, each sewer-and-sewing-machine being a small island populated by large stacks of incoming fabrics and other supplies, and each sewer sitting at the sewing machine all shift doing repetitive work. This batch-and-queue mode is a good deal worse—for body and mind—than that in the office example (buy, invoice, pay), in which the operatives are not chained to a machine and can move/walk around at will. Although organization of cut-and-sew into cells has long been known—sometimes referred to as modular sewing or Toyota sewing system (TSS)—and strongly advocated (e.g.,* Sobuj 2018*), the industry resists its use.*

Quality and CM

When productive resources are arranged into a small cluster dedicated to a narrow family of products, services, or customers, we call it a cell (more properly *cells*, plural)—the mode of cellular production, cellular operations, cellular organization, cellular layout, or *cellular management* (CM) (Suresh and Kay 1998; Proctor et al. 2007). Whatever the name, it is (if done reasonably well) multiply beneficial (Hyer and Wemmerlöv 2002). Following is a summary of those benefits (Schonberger 2008, 23–4):

> Cells draw the processes close together in time and distance. Defectives show up quickly while colleagues at an earlier station often can still see and correct the cause forthwith. If they are not fixed right away, problem-solvers, blessed with a warm trail of causes, have good chances of finding and rooting out the causes. Costs of scrap and rework fall or are avoided, yielding savings that directly fall to the bottom line.

Measures of performance

Notable, in that brief summary on benefits of CM, is that it features mostly low-level performance indicators; that, it seems, is a hallmark of cellular thought. In contrast, many or most other management initiatives lead (or tempt) researchers to investigate benefits in more aggregated terms, from labor productivity and cost per unit, to sales revenue and market penetration, to net income and the stock price (e.g., Garcia-Bernal

[3]This kind of batch processing of office documents , having the merit of being easy to visualize, is no longer the norm in advanced economies in which the tasks are consolidated though office automation; however, it is still commonplace in many developing countries, and remains normal among smaller businesses.

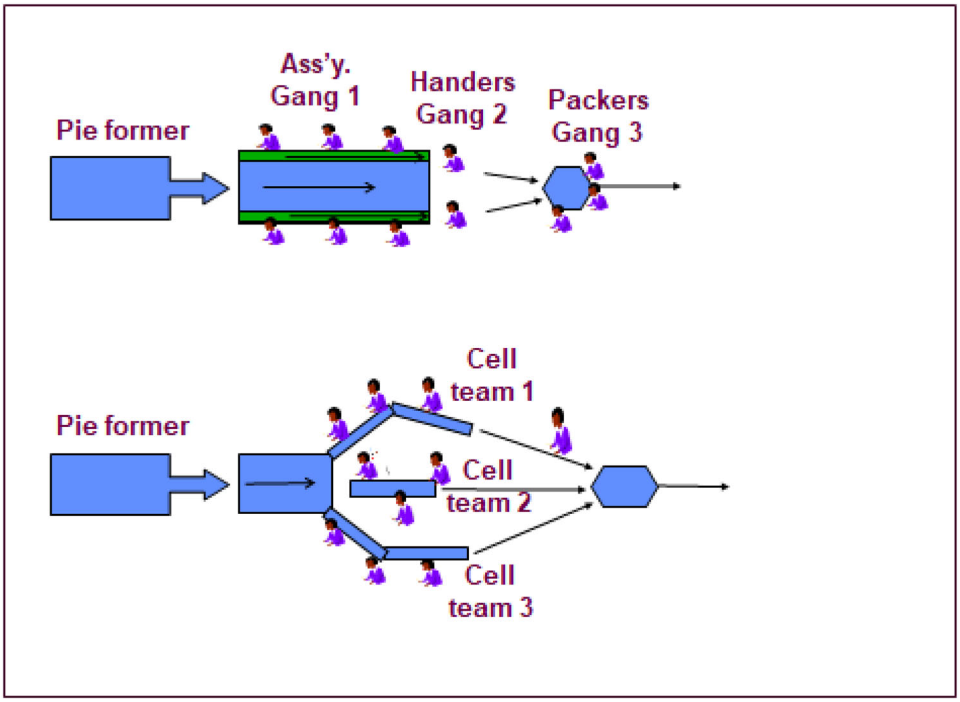

Figure 2. Assembly gang mode restructured as cell teams.

and Ramírez-Alesón 2015; Vicencio-Ortiz and Kolarik 2012). There is, however, a substantial body of knowledge that argues for less of that, and relying more on simpler, more direct performance measures. Rather than in "aggregated and monetized (accounting system) indicators," Hall (2014) observes that process-improvement is better and more convincingly assessed in "natural units," such as defects and rework, flow time and lead time, on-time deliveries, and evidences of flexibility such as a multi-skilling matrix. Those natural data are well suited to display as graphical trends in each work center—elements of visual management (Fullerton and Wempe 2009; Galsworth 1997; Greif 1991; Hirano 1998), the better to keep work forces alert to and involved with continuous improvement (Huntzinger 2007; McIlhatten 1987).Then, too, there is the long-standing viewpoint that measures such as productivity tend in practice to act, disturbingly, as tradeoffs with measures of quality. Correctively, Grover and Walker (2003) and Cua, McKone-Sweet, and Schoeder (2006) are among those who, reasonably, call for "multiple measures [of manufacturing] performance"; for a highly detailed review of performance management in quality management, see Rezaei, Çelik, and Baalousha (2011).

Quality woes on assembly lines

Eklund (1995, 19), in his in-depth case study of a European car assembly plant, found that quality deficiencies became more numerous "the further the car advanced on the assembly line," explaining that "early deficiencies were built in" and therefore unnoticed "by assemblers down the line." Those concealed errors "may have made a subsequent assembly operation impossible to perform correctly." At the time of that case study (early 1990s) plant management had only recently and minimally introduced multi-skilling, that lag likely contributing to the high rate of observed quality deficiencies and their build-ups along the line—and which called for a large, well-staffed repair area at line's end. (All automotive assembly plants still have sizeable end-of-line repair areas.) Plant leadership—either lacking knowledge in advanced practices in quality management or in motivation to act on them—had just been replaced by new management with better intentions. Too late, though: the plant was closed soon after Eklund's case-study research was completed.

Teams replacing gangs

Based only on the Figure 1 schematic (detailed specs are not available), it is possible to roughly devise a three-cell alternative to the three-gang configuration. Figure 2 schematically depicts (not at all to scale) the existing gang method on top and a cellular replacement below it. The cellular mode has the present central conveyor shortened by half, and eliminates the two narrow conveyors in favor of hand-to-hand or gravity handling: simple, low-cost, low maintenance, high reliability, easily movable facilities. The three cells stemming off the main conveyor consist of narrow assembly benches, each staffed by a cell team of three. Cells 1 and 3 need to be angled so that packed cartons end up in a central area for subsequent transport to shipping. At bench-side, the first packer grabs two small cartons from the pie-delivery conveyor and loads them with pies; the second packer grabs the small cartons and packs them into the bigger carton; and the third packs cartons into larger boxes and moves the boxes forward to the collection area ready for transport. This configuration totals nine packers. A tenth person serves as lead person who helps coordinate everything, including job rotation, and fills in whenever needed.

All cell team members are multi-skilled and by management policy engage in frequent job rotation, such as a minimum of every four hours—with the packers free to decide the rotation details. They may see it in their interests to arrange themselves according to how experienced and speedy they are; for example cells 1 and 2 might be for more-adept packers, and cell 3 for learning-on-the-job newcomers and/or perhaps workmates with handicaps. Doing so engenders fairness, as well as cost-efficiency.

In designing such a cellular structure the plant may employ the expertise of industrial and systems engineers (Buchanan and Preston 2007). In keeping with a traditional objective of cost-efficiency, the ISEs would lay out the cells and establish required average output rates and staffing based on human norms (Hodson 1992, 13.105–13.107), with consideration of ergonomic effects. They continue with designing and balancing the lines (Industrial Engineering Knowledge Center (no author) 2019). This designing/balancing, however, "fails to take advantage of the higher skill or proficiency of individuals who are above and overstresses those who are below average" (Lee 2020, 38). Correctively, ISEs, for the most part, are to bow out, as the cell team and team leader or supervisor take over assigning of packers to the cells with adjustments to individual capabilities; and, in best-case management, are empowered to consider and adopt ergonomically beneficial work benches and positioning of implements (Noro and Imada 1991; Wilson, Haines, and Morris 2005). Further—and this is often a primary advantage of cellular structures—each cell may be dedicated to a different size or type of container, that level of focus being a boon to operator skilling and product quality. (Note: A close partner of the focused cell is the focused factory—both contributory to skilling and product quality: Schroeder and Pesch 1994; Shafer and Oswald 1996.) Many other best practices in team management, self-management, and quality management blend in Lee (2005) and Schonberger (2014).

This cellular structure of Figure 2 is one of multiple short-but-strong chains of responsibility aimed at delivering high quality and reliability: Each three-person cell team has its own simple facilities in which sources of error isolate to the cell, cell station, and person so as to stand out for quick correction—such pinpointing serving to avoid the blame game and its animosities. The mode fosters friendly and useful competition and sharing among the cells; on quality, reliability (including attendance and on-timeliness, and steadiness of output), problem-solving/process-improvement ideas (Eklund 1997; Molleman, van Delft, and Slomp 2001), and multi-skilling attainments, as posted on a versatility display. Other advantages of this cell setup are simplicity—little equipment complexity and things to go wrong—minimal cost in setting it up, and flexibility in making changes to it. (Such conditions of minimal complexity in smallish production contexts are explored in Falck, Örtengren, and Rosenqvist 2014; Kogi 2008. See, also, the kinds of configuration issues that arise in the emergent context of 3 D printing, Hedenstrierna et al. 2019). Any concern that multiple cells would cost more than a single production line has, therefore, no merit—except in certain special cases, such as automobile assembly lines, briefly considered next.

Cells replacing production lines

Is it feasible to build or replace a high-volume car assembly line, such as the one in Eklund's case study, with cells? The answer is no, and the reason is that the massive size, output quantities, and buildings needed for such car assembly limit practical ways they can be assembled. Cellular production, though inappropriate in volume car assembly, is commonplace for many of the thousands of component parts and modules that go to car assembly lines from component suppliers. (It is ironic that much of the literature of lean manufacturing prominently refers to high-volumne automobile assembly lines, when CM, among the most effective of lean/flow methodologies, is unfeasible there.) Further, small vehicles such as motorcycles and golf carts can, should be, and are assembled in cells—typically each family of models produced in its own cell. That is the case at Polaris in Spirit Lake, Iowa, which assembles each of two models of Indian motorcycles on model-dedicated lines and its more complex Victory bikes in four model-dedicated lines (Weber 2015).

> Proviso: Because this article's focus is largely on issues involving human operatives, the mode of highly automated production is omitted. That exclusion applies—besides and quite differently from automotive assembly lines—to high-volume manufacture of most foods and beverages and many other smallish consumer goods. Such production is characterized by highly automated, ultra-fast, complex, high-maintenance, failure-prone, conveyor-driven fill-and-pack lines in which the operators' main jobs are re-stocking filling and packaging equipment, and rushing to sources of innumerable line stoppages and slowdowns. For insights on that mode, see Schonberger (2019b).

Summing up

These pages have brought together disparate concepts, contentions, and advisories, all centering on productive operations of two or more persons—in both manufacturing and services. Within that multi-person context, instead of one or two or three main themes, there are several. This final section aims at sorting them out in some semblance of a summary, along with their implications.

Most of this article's segments deal with workplaces: poor to best *workplace configurations*, and most beneficial *workplace-management* practices, both judged in terms, primarily, of quality and employee work lives. Among configurations, those cited as poor are twofold, each defined in terms of physical space and task variety: One (exemplified by the cartoning of small pies, Figure 1) is tight clusters of operatives, all performing the same task, with no chain of responsibility. The other is a sequential work flow stretched out to where there is little visual or vocal contact from person to person (e.g., shop to shop, office to office work flows). In both cases the cellular configuration is an advantageous alternative.

The cellular mode, though, is more than a configuration: Cells—broadly understood—are enablers of advanced workplace management, centering on two features: cell-team responsibility over the processes, their quality, and their improvement; and systematic multi-skilling with frequent job rotation. Such responsibility applies beneficially in designing jobs that enhance output quality, and physical health and safety, along with improved mental health and work-life satisfaction.

These messages are aimed at organizational managers whose responsibilities include ensuring high-quality outcomes and employee safety and health. Equally, they're directed toward professionals with special expertise in designing workplaces and assisting in their implementation. Their responsibilities include critically examining existing modes of multi-person operations and correcting defective elements, and building, promoting and demonstrating organization-wide understanding about the beneficial application of cellular management with multi-skilling and job rotation.

A further intent is that relevant agencies, academics, and professional organizations imbue their policies, literature, and training materials with the CM concepts examined in this article, thus to further theory and practice in obviating poor workplace and job designs and their deficiencies in process and quality management, and raising the profiles of effective ones.

As regards academic research, primary avenues should include case-study methods (Eisenhardt 1989) aimed at bulking up theory on multi-person workplaces in a wide swath of contexts. Promising topics include: explications on less and more effective workplace configurations as regards effects on work-force physical and mental health and safety and their contributions to process improvement; presenting and validating propositions centering on the CM concepts addressed herein; and reaching out into the realms of advanced technologies in which process designs tend to obscure or minimize the linkages between process designers, maintainers, and operators.

About the Author

Richard J. Schonberger is a Bellevue, WA-based independent researcher/author and many-year member of ASQ, and a member of the IISE's Industry Advisory Board. Formerly a practicing industrial engineer, Richard later received a Ph.D. from and joined the faculty of the University of Nebraska, becoming George Cook Professor in operations management and infosystems; later affiliate professor in management science, University of Washington. He is author of 16 text and professional books, including *Japanese Manufacturing Techniques* (Free Press, 1982)—the first book in English detailing JIT/lean management principles and methodologies; and *World Class Manufacturing* (Free Press, 1986). His latest is *Flow Manufacturing – What Went Right, What Went Wrong: 101 Mini-Case Studies that Reveal Lean's Successes and Failures* (Routledge/Taylor & Francis, 2018). His 200-plus articles have appears in a wide range of academic and practitioner periodicals. Richard's honors include: 1995 Shingo Institute Academy; 1990 British Institution of Production Engineers' International Award in Manufacturing Management; and 1988 IISE Production and Inventory Control Award.

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