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On the Interface Between Operations and Human Resources Management

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On the Interface Between Operations and Human Resources Management

Abstract

Operations management (OM) and human resources management (HRM) have historically been very separate fields. In practice, operations managers and human resource managers interact primarily on administrative issues regarding payroll and other matters. In academia, the two subjects are studied by separate communities of scholars publishing in disjoint sets of journals, drawing on mostly separate disciplinary foundations. Yet, operations and human resources are intimately related at a fundamental level. Operations are the context that often explains or moderates the effects of human resource activities such as pay, training, communications and staffing. Human responses to operations management systems often explain variations or anomalies that would otherwise be treated as randomness or error variance in traditional operations research models. In this paper, we probe the interface between operations and human resources by examining how human considerations affect classical OM results and how operational considerations affect classical HRM results. We then propose a unifying framework for identifying new research opportunities at the intersection of the two fields.

Keywords

work, HRM, job, organization, managers, operations, research, training

Disciplines

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WORKING PAPER SERIES

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Working Paper 02 - 22



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Abstract

Operations management (OM) and human resources management (HRM) have historically been very separate fields. In practice, operations managers and human resource managers interact primarily on administrative issues regarding payroll and other matters. In academia, the two subjects are studied by separate communities of scholars publishing in disjoint sets of journals, drawing on mostly separate disciplinary foundations. Yet, operations and human resources are intimately related at a fundamental level. Operations are the context that often explains or moderates the effects of human resource activities such as pay, training, communications and staffing. Human responses to operations management systems often explain variations or anomalies that would otherwise be treated as randomness or error variance in traditional operations research models. In this paper, we probe the interface between operations and human resources by examining how human considerations affect classical OM results and how operational considerations affect classical HRM results. We then propose a unifying framework for identifying new research opportunities at the intersection of the two fields.

On the Interface Between Operations and Human Resources Management

1. Introduction

The fields of Operations management (OM) and human resources management (HRM) have a long history of separateness. In industry, it has been rare for an operations manager to become a human resources manager or vice versa. In academia, the two subjects have been studied by essentially separate communities of scholars who publish in nearly disjoint sets of journals. Despite this, operations and human resources are intimately tied to one another in virtually all business environments.

For example, consider the case of a Big Three auto company power-train facility with a history of poor budget performance and low efficiency. In spite of a high-profile corporate emphasis on lean manufacturing and the best efforts of the company's lean engineers and six-sigma black belts, the plant continued to underperform until 2001 when a new plant manager took over. Immediately recognizing that the primary cost driver was throughput (failure to make production quota during regular time required expensive overtime), he zeroed in on the largest source of output loss, blocking and starving in the line. But, because he knew that the majority of stoppages were due to people-induced disruptions, the new manager eschewed the traditional OM focus on equipment-induced causes and worked instead to involve operators in the problem solving process.

Several months were spent educating the workforce on the drivers of performance (e.g., the importance of bottlenecks) and setting up mechanisms for formally recognizing people for their successes (in non-monetary ways, since this was a union facility). In less than a year, the plant was transformed into one of the best performers in the company, despite a down economy.

The lesson from this story is that human considerations can be vital in the success of operations improvement programs. By helping workers to understand the implications of the

OM design for their work and then motivating them to act accordingly the plant turned around its performance.

But simply acknowledging human considerations such as motivation is not enough. Consider the case of a circuit board plant of a large computer manufacturer that was also plagued by low throughput. Recognizing that worker contributions were essential, management embarked on a motivational campaign, which included shirts, pep talks and illuminated signs with slogans such as “I love my job.” Not only did these efforts fail to promote higher output, but also the workforce was put off by them and became cynical about improvement efforts in general.

Eventually, the circuit board plant adopted an alternate approach, which made use of both OM principles and a more sophisticated understanding of motivation. It included training the workers in the principles and key success variables of pull systems, investment in additional capacity that gave work teams more ways to share and combine tasks, and installation of new control systems that the workforce understood. Throughput was doubled within months; total cycle time was slashed by three quarters in a year.

The lesson from this story is that a clear operational focus can be critical to the success of human relations initiatives. Only when the workforce was provided with appropriate vision and tools were people really motivated to make changes.

Interestingly, these results are precisely what psychological research on goal-setting would predict, as decades of behavioral research shows that hard, specific goals produce superior performance to more vague and general goals (Locke 1982; Locke and Latham 1984) and that worker “line of sight” regarding how their actions affect outcomes enhances performance (Boswell 2000, Lawler 1999, Vroom 1964). Yet, such research findings seldom find their way into scholarly discussions of operations management, and even more rarely are they known by operating managers. By the same token, behavioral scientists, HR managers and industrial psychologists working in organizations rarely incorporate the OM context in a way

that would reveal which particular goals and which particular motivational connections are most important.

The OM/HRM Interface: A Framework

Ultimately, performance of production systems (both manufacturing and service) is vitally dependent on effective management of the interface between OM and HRM. To understand how and to help us identify research opportunities on this interface, we propose a framework of factors required by people to perform their jobs.

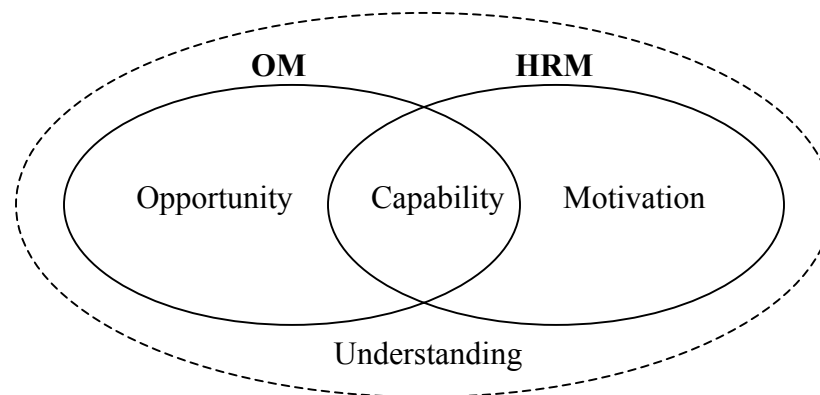
1. Capability: The skills, knowledge and abilities necessary to execute an action associated with the objectives of the organization.
2. Opportunity: When individuals are provided or encounter situations in which actions can be executed with the desired effect.
3. Motivation: The drive to execute those actions, created by a perception that they are linked to desired outcomes and rewards.
4. Understanding: Knowledge of how an individual's actions affect the system and overall goal achievement.

The first three components are derived from a long research tradition suggesting that individual performance is a multiplicative function of ability and motivation (Vroom 1964, Maier 1955, Cummings and Schwab 1973), subsequent critiques of the simple model (Campbell and Pritchard 1976) that suggest that the environment determines the expression of ability and motivation (Gilbreth 1909, Dachler and Mobley 1973), and recent work suggesting that situational constraints and opportunity are key to a theory of work performance (Peters and O'Connor 1980, Blumberg and Pringle 1982). We have added the fourth component, understanding, to help describe the OM and HRM interface.

Figure 1 schematically illustrates the relationship of these four areas to the OM and HRM functions. Although it may be simplistic to assign "opportunity" exclusively to OM and "motivation" exclusively to HRM, we do this to emphasize that the interface we are interested in is mainly concerned with "capability" and "understanding". It is our view that deep appreciation

of these is the key to developing systems in which OM and HRM work in harmony to produce high performance systems.

Figure 1: The OM/HR Interface.



The automotive example (given earlier) illustrates a case of emphasizing opportunity without sufficient motivation, while the circuit board example illustrates a case of emphasizing motivation without sufficient opportunity or understanding. In both cases, the workforce was left unable to achieve organizational goals, and the solution involved training people to understand the links between their actions and the performance of the system.

In these examples, the innovations did not emanate from the HRM staff, but instead were the primary responsibility of OM managers. However, they both illustrate the following point: *What matters is integrating the ideas of OM and HRM across the organization.* This is also a common theme in HRM. Somehow, managing people must become an integral part of the job of “line” managers in manufacturing and service operations, not simply the domain of the HR “staff function” (Ulrich 1997). Thus, the interface of OM and HRM is a key element of the transformation of HRM from a staff function or professional practice to a decision science (Boudreau and Ramstad, in press; 2002).

The main thesis of this paper is that the interface between OM and HRM is a fertile source of research opportunities. Methods for better incorporating human behavior into OM models will

yield more realistic insights. Incorporating operations context into HRM theories will make general theories more contextually precise, and will help identify new ways for HR practices to add value.

The remainder of the paper is organized as follows. Section 2 describes OM situations in which human considerations may have a major effect. Section 3 provides a corresponding range of HRM situations in which operational context can be of major importance. Section 4 develops a taxonomy of research categories for the OM/HRM interface, and Section 5 presents concluding remarks. It is our hope that this summary will stimulate OM researchers to consider HRM issues, HRM researchers to consider OM issues and at least a few brave researchers to venture into the interface directly.

2. The Impact of Human Resources on Operations Management

Simplification is an essential part of all modeling, and OM researchers and managers are aware that their models involve simplified representations of human behavior. But they may not always be aware of the consequences these simplifications can have on decision making. To gain insight into this issue, we begin by listing some of the most common assumptions used to represent people in OM models. We then give a number of examples where more realistic consideration of human behavior can have a significant impact on conclusions. Finally, we discuss previous and potential future research.

The following assumptions are commonly used to simplify human behavior in OM models.

1. People are not a major factor. (Many models look at machines without people, so the human side is omitted entirely.)
2. People are deterministic, predictable or even identical. People have perfect availability (no breaks, absenteeism, etc.). Task times are deterministic. Mistakes don't happen, or mistakes occur randomly. Workers are identical. (Employees work at the same speed, have the same values, and respond to same incentives.)
3. Workers are independent (not affected by each other, physically or psychologically).
4. Workers are "stationary." No learning, tiredness, or other patterns exist. Problem solving is not considered.

5. Workers are not part of the product or service. Workers support the “product” (e.g., by making it, repairing equipment, etc.) but are not considered as part of the customer experience. The impact of system structure on how customers interact with workers is ignored.
6. Workers are emotionless and unaffected by factors such as pride, loyalty, and embarrassment.
7. Work is perfectly observable. Measurement error is ignored. No consideration is given to the possibility that observation changes performance (Hawthorne effect).

While assumptions such as these can greatly simplify the mathematics, they can omit important features. For example, consider the situation in 1985, at a plant that was a joint venture between Yokogawa Electric and Hewlett Packard (YHP) where electronic circuit boards were “stuffed” manually with a wide variety of components. Although this plant had less automation and greater product variety than other HP plants, it nevertheless had the highest level of productivity in its category. The reasons had to do with the workers and their “talents.”

We use the term “talent” broadly, to refer to the potential for workers to affect organizational processes and outcomes. Talent pools are often formally described in such things as job titles, competencies, knowledge and certifications, but many worker talents are less obvious. For example, a call-center operator’s job description may say very little about handing off work to co-workers, yet this talent may be one of the most pivotal in enhancing the effectiveness of the queuing process.

Returning to the YHP example, this plant had a simple flow-line design. Each worker was assigned several types of components which they manually placed on circuit boards. Work-in-Process Inventory (WIP) was (usually) physically limited to two boards between successive workers. Given the product variety and limited WIP, standard OM models would have predicted a large amount of blocking and starving (work stoppage while waiting for another worker to finish). However, workers and managers had come up with a scheme that avoided idle time. The key element was task sharing. For example, the first worker always placed components 1-4 and the second worker always placed components 7-10, but components 5 and 6 were placed

by whichever worker was “ahead.” We called this “On-the-fly Line Balancing” because tasks were reassigned in real time to compensate for a temporary imbalance that would otherwise cause blocking or starving (Sox, et al. 1992).

There is a clear OM explanation of why the new operating method should be effective; worker flexibility was used to smooth out variations in workload. The OM model of this process assumes that workers switch tasks at appropriate times, and that the new system will make no difference in the quality of component placement. From an HRM perspective, such assumptions have significant implications for talent. Workers must be able to modify the design of their workspace, be capable of placing the additional components, understand when to switch from their “normal” task, be motivated to take on the extra work at the appropriate time, and understand how their task-switching decisions improve overall throughput and avoid idle time. Also, the task-sharing approach meant that it was very difficult to observe individual contributions (point 7 above). The workers did have pride in their unit, and they did cover for each other on breaks and for tiredness (points 3, 4, and 6).

These and other human issues have the potential to “move the needle,” that is, to materially improve or detract from the predicted outcome of an OM policy. Yet, neither the OM model nor HRM frameworks incorporated these effects, nor explained how training, selection and other HRM variables might lead to the positive result of this worker-induced change.

This realization applies to many other situations that have long been studied by OM scholars. For example, OM research on services often address capacity, availability of servers and scheduling. HRM research has addressed complementary issues such as how services can be designed to improve performance (Cook et al. 2002 and Batt 1999). These are but a few examples where HR and OM have complementary roles, and where research at the intersection may shed light on innovations that integrate OM and HRM to move the needle.

2.1 Where Can Human Resources Management Inform Operations Management?

One way to address this question is to consider settings that have been modeled mathematically. If the OM-recommended policy is either more effective or less effective than

predicted by the model, then the question arises of what human factors might explain the difference. For instance, in the previously cited example of a Big Three powertrain plant, a standard transfer line model would predict a much higher throughput than was being observed. This would be a clue that important human factors may have been overlooked.

Once a feature of human behavior has been recognized, incorporating it into the analysis can lead to better OM models. For example, many classical operations models assume that people are like machines, effectively identical to one another and exhibiting only random performance variation (e.g., Hillier and Boling 1967 and Conway et al. 1988.) Yet, individuals differ in skills, speed and many other characteristics; this is the most basic of HRM and industrial psychology insights. So, it is not surprising that some of these classical models do not match reality very well. Some OM models do recognize that people possess different skills that allow them to be assigned differently to a set of tasks (e.g., Bartholdi and Eisenstein 1996, Buzacott 2002, and Hunter, et al. 1990). But these models retain the assumption that within-individual variation is random (or perhaps non-existent), which conflicts with the HRM insight that workers observe and respond to the context of their work in non-random ways. OM models that include such factors could create a link between OM principles and the HRM investments that attract, retain and develop workers, and affect their responses to their environment.

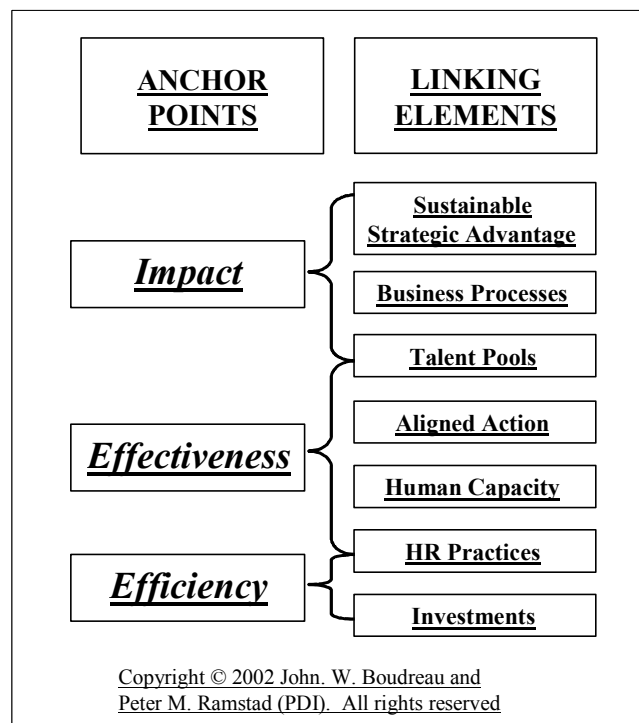
Flexibility has been a hot topic in the OM literature. Many of the models focus on cross training, which enables workers to help each other in a manner that avoids some of the counterproductive effects of variability. Examples include analyses of Bucket Brigades (Bartholdi and Eisenstein 1996), Dynamic Line Balancing (Ostolaza et al. 1991) and “worksharing” (Bischak 1996, Zavadlav et al. 1996, and McClain et al. 2000). But whether and where cross-training will actually increase productivity in practice depends on a number of HRM concerns. Do frequent changes of tasks interrupt the rhythm of an operation, causing workers to slow down? Worker perception of fairness affects whether and how they help one another (Bowen et al. 1999, Rousseau and Shalk 2000, and Hartman, Yrle and Gail 1998). Does that help or hinder system output? Reward systems affect how people respond to work instructions

(Luthans and Davis 1990, Ichniowski et al. 1997 and Ichniowski and Shaw 1999). How does method of pay affect worksharing operations? Workers lose proficiency in skills that are used infrequently (Goldstein 2002, Noe 2002). If that is including in an OM model, can we identify a limit on the benefits of cross-training?

The HC BRidge™ Framework¹, shown in Figure 2, links human resource investments, organizational talent and strategic success (Boudreau and Ramstad 2002). This helps in depicting the OM-HRM interface in its larger organizational context. OM typically focuses near the top of the diagram, on issues relevant to “Business Processes” such as low-cost, speed, quality and productivity. HR typically operates lower in the diagram on “HR Practices” and their effects on “Human Capacity” such as capability, opportunity and motivation, performance ratings and turnover. The OM-HR interface lies in the middle, the boxes labeled “Aligned Actions,” “Talent Pools,” and “Business Processes.”

Figure 2

The HC BRidge™ Framework



¹ HC BRidge™ is a trademark of the Boudreau-Ramstad Partnership.

Integrating OM and HRM improves our ability to use business process principles to reveal the workers or Talent Pools that are most pivotal (affect process outcomes the most), and their behaviors that create those process effects (“Aligned Actions”). In this section, we are looking from “Business Processes” toward “Talent Pools,” asking what human and HRM elements might most enhance OM processes and models. In Section 3, we will look from “Talent Pools” toward “Business Processes,” asking what OM context elements might most inform HRM theories and practices. Figure 2 shows how important this interface is to an organization, providing links all the way from “Investments” to “Sustainable Strategic Advantage”.

Ideas for better incorporating HRM issues into OM modeling and practice can come from theory and experience. We can use HRM theory to refine an OM model by more accurately representing human behavior, or we can observe the OM concept in practice and adjust the model according to human responses.

2.2 Research at the HRM/OM Interface

Since almost all operations systems involve people, the list of specific OM results that might be affected by human behavior is virtually unlimited—a comprehensive list is not feasible. Instead, we offer the following areas as examples of situations where mainstream OM results may be affected by human considerations. For each, we note the classic OM insight and a contrasting HRM observation. These are chosen to address potential “un-addressed talent issues,” which might allow or cause workers to move the performance needle, and thus could alter the OM insight. Research already exists for some of the topics, but for most the HRM effects on the OM result remain conjectures in need of research attention.

Inventory as a Buffer

Use of inventory buffers to mitigate the impacts of variability is a practice as old as manufacturing itself. Indeed, some of the oldest results of the OM field (e.g., base-stock formulas) deal with the problem of setting appropriate inventory levels.

OM: In serial production lines with variable tasks, more WIP reduces blocking and starving, and hence increases output.

HRM: In some cases workers speed up when a queue grows (Edie 1954.) WIP provides a signal to workers. Observing the rise and fall of WIP indicates “who is getting more work done,” which might induce a change in work pace. Changes in WIP are less obvious when inventories are very high. Therefore, workers are more likely to link their speed of operation to “changes in WIP” in a low-inventory system than in an operation that has large amounts of WIP.

Previous research:

- (1) Doerr et al. (1996) and Schultz et al. (1996) compared work pace in low-inventory lines and high-inventory lines. This research suggested that average work pace is faster in low-inventory lines, enough so as to compensate for loss due to blocking and starving (17%). However, results differed for slow workers and fast workers.
- (2) Schultz et al. (2003) studied motivational effects of different forms of visible feedback and concluded that visible performance feedback increases work pace. Reducing ambiguity of feedback enhances this effect.

Server Pooling

Scheduling and assigning labor resources has long been a focus of OM research. Recent years have seen an increase in interest in the practice of cross-training workers to cover multiple task types (see e.g., McClain et al. 2000), and on the effects of queue length on customers and workers (Taylor and Fullerton 2000, Zohar, Mandelbaum and Shimkin 2002, Schneider, Ashworth, Higgs and Carr 1996.)

OM: Pooling (servers sharing the same source of customers) reduces idle time by avoiding the situation where one server is idle while another has a queue of customers or tasks. In a mixed-model assembly line, pooling may be achieved by cross training and flexible task assignments. A similar effect occurs in call centers, where cross training not only provides pooling, but also increases the likelihood that a given customer’s needs can be met by a single worker, thus avoiding time loss caused by handing off a task.

HRM: Theories of learning suggest that practice enhances and maintains proficiency, so there is likely an upper limit to the effectiveness of cross-training (Gill 1997). If too many tasks are trained, lack of regular use as well as cognitive limits may cause productivity losses due to forgetting (Goldstein 2002, Noe 2002, Argote and Eppler 1990).

Previous research: Schultz et al. (2003) studied the effects of short work interruptions and found that short work interruptions reduce average work pace, but not for all workers.

HRM: Individuals are more motivated when they perceive they have choice, discretion and some control over their work (Hackman 1978, 2002). Individuals tend to choose tasks they do best, that are the easiest, most familiar or most satisfying. Do they choose the “wrong” task (operationally), rather than the one that does the system the most good?

Proposed research: Study the effect that “allowing choice of task” has on output, especially in situations when it is optimal not to have choice for OM reasons.

HRM: Training costs are significant, as are pay differentials to retain cross-trained workers. Opportunity for cross-training may enhance the ability to attract workers, but cross-trained workers may also be more marketable and prone to leave (Batt and Osterman 1993, Bishop and Kang 1996). Increased behavioral costs of compensation, turnover, attraction and retention (Cascio 2001) may materially affect the estimated returns from cross-training in OM models. OM models are generally naïve with regard to such costs, which may have significant effects on the optimal levels of cross-training.

Proposed research: Study the effect of cross training on attraction and turnover and on system output. Study differences across workers. Estimate the cost implications of increased rewards, turnover, etc.

Team Build

Recent OM practice has seen a trend toward using teams of various types in the workplace. In contrast to the highly specialized division of labor prevalent in most assembly lines, teams offer the potential for workers to share labor in a dynamic fashion. An extreme version of this practice is that of “team build,” in which a group of workers collaboratively produce a product from beginning to end. (Volvo’s experience with this will be discussed later.)

OM: Handoffs between production stages may cause idle time. When workers collaborate on a job and follow it through all production stages, blocking and starving can be eliminated, and variation in task time can be accommodated by flexibility of skills and assignments. Hence, “team build” should outperform “specialized work” (Van Oyen et al. 2001). A team setting may also allow the most effective worker to do a larger fraction of the work (Buzacott 2000). Many OM authors have written about how best to utilize teams to achieve the desired objectives of speed, quality and cost (Iravani et al. 2002, Suri, 2001 and Suri 1998, for example).

HRM: Proficiency varies with skill similarity. Can people get good enough at a wide variety of tasks? A “complete product perspective” requires that workers understand the

connection between the complete operational result and their own individual efforts and rewards.

Proposed research:

- (1) Vary skill similarity and/or work variety across production tasks. Observe changes in task speed and the total effect on productivity in a specific context.
- (2) Vary visible completion of a product, working in teams, and combinations of these factors. Vary or measure task identity (Hackman 1978, 2002) and team ability to assign tasks (Brannick, Salas and Prince 1997, Guzzo and Salas 1995).

Customer Contact and Quality

Since the 1980's, the OM field has had a strong focus on quality, both internal and external. Many practices were motivated by the desire to improve product and/or service quality.

OM: Industry examples where “team build” systems were adopted at least partially to improve quality of customer contact include Deere and R.R. Donnelley (Van Oyen et al. 2001). Can OM models help to specify the optimum levels of such quality variables, depending on the costs and revenue effects? Also, the types of errors that lead to service failures tend to be predictable, applying knowledge and methods from cognitive psychology research (Stewart and Chase 1999.)

HRM: There are service quality and time tradeoffs in any customer interaction. OM may be able to identify the optimum quality level, but can employees be trained to analyze tradeoffs accurately? What internal models do employees create to guide their decisions about a service level that is “good enough?”

Proposed research: Create a laboratory situation with a clear, measurable objective based on service. Vary the training and information available and analyze overall performance and the mental models workers use to set their quality standards.

Bucket Brigades

A specific form of worker organization designed to facilitate work sharing is that of “bucket brigades,” in which workers move upstream and “bump” upstream workers for their jobs whenever they become idle. Such systems have been described for sewn products (Bartholdi

and Eisenstein 1996a), warehouse picking (Bartholdi and Eisenstein 1996b), and other environments.

OM: In Bucket Brigade production, putting the fastest worker last achieves a stable system, often with maximum output (Bartholdi and Eisenstein 1996). However, if bumping is not allowed (i.e., workers must complete an operation before handing a job off to another worker), the optimal order may change (McClain et al. 2000.)

HRM: Processing time is affected by the speed of proximal workers. Specifically, the position of fastest worker may affect the speed of surrounding workers.

Proposed research: Vary the position of the fastest worker in Bucket Brigade and other work sharing systems. Observe the effect on proximal-worker speed and the implications for system output.

Kanban and CONWIP

Since being made famous by Toyota in the 1970's, pull production has been both widely used and widely studied. A particularly active line of research has been on how to implement pull. Although Toyota actually used a variety of implementations, the version of Kanban originally associated with Toyota rigidly controlled each station in a line by not permitting production until consumption of inventory at a downstream station provided authorization. Because Kanban was intrinsically restrictive, authors and practitioners have proposed a variety of more flexible versions of pull systems.

OM: Fewer constraints improve system performance. Kanban systems restrict the amount of inventory at each station of a line, whereas CONWIP (Spearman et al. 1990) only restricts the total inventory. Hence, CONWIP should achieve higher levels of throughput (Spearman and Zazanis 1992, Spearman 1992).

HRM: Processing times are affected by between-worker communication. Does the act of "pulling in" Kanban markers improve communication and problem resolution?

Proposed research: Implement variations of pull systems in a system with complex and changing task requirements to measure effect of learning and communication induced by pull activities.

OM: One of the benefits of low-inventory operation has been attributed to better problem solving due to a shorter time lag between incidence of a defect and its discovery. Yet, in

a Toyota Motor Manufacturing case (Mishina 1992) workers did not remember anything unusual about defective seats, when asked after several days had passed.

HRM: Training can improve many aspects of job performance.

Proposed research: Investigate whether training and/or communications initiatives can improve recollection of the sources of defects, and whether there is a synergy between such initiatives and the lag-reducing benefits of low-inventory operation.

While this list of topics is by no means complete, these examples demonstrate that human considerations can have a powerful impact on the conclusions from an OM model, and that there are many opportunities to better incorporate HRM insights into OM research and practice.

2.3 Systemic Changes in Our Approach to OM Research

There are many ways in which human variables affect OM. The list below is not meant to be complete, but captures some major dimensions along which we have observed HRM variables affecting OM systems. Our impression is that OM scholars are familiar with these (and use them in consulting assignments) but often leave them out of their research.

1. Individual productivity is affected by many variables, such as:
 - a. Incentive systems, learning and forgetting, tiredness, boredom and other workload-influenced factors.
 - b. Retention/turnover effects on individual performance and system training costs.
 - c. Flexibility and agility, which influence how effective a worker can be in a dynamically changing system.
 - d. Motivation, or psychological reaction of a worker to his/her environment that produces the desire to behave in certain ways. Motivation can have a powerful influence on speed, quality and almost every other aspect of worker performance.
2. Team structure affects performance of individuals and the overall system.
 - a. Other workers' abilities affect performance either positively (e.g. facilitating learning or increasing motivation) or negatively (e.g. encouraging slacking).
 - b. A team setting may allow the faster worker to do more than his/her share of the work, thereby increasing productivity.
 - c. A team setting allows increased communication, which can increase or reduce productivity in several ways.
3. Information is a design variable that affects performance.

- a. What people know affects their ability to identify and perform tasks.
 - b. When and how people get information can make a big difference (e.g. quick feedback, in an easily understood format, is most effective.)
 - c. Clarity of information and connection to organizational goals is important to ensuring that information is converted into useful knowledge.
4. Problem Solving is important to long-term system performance.
- a. Cross training implies more minds to examine a process and therefore can provide better solutions and flexibility for dealing with uncertainty.
 - b. Rotating workers gives them a system-wide perspective that may motivate workers or enable them to redesign the process.
 - c. Shorter queues may improve the ability to determine what caused problems. (If the time between creation and detection of a defect is long, people may forget factors important to determining the underlying cause of the problem).

Many of the above examples illustrate both positive and negative effects on productivity. We believe the total effect will depend on the details of the situation, and therefore needs to be established by research targeted at specific environments. The ultimate result of such research will be OM models that are richer and more realistic with regard to how they represent humans and their interactions with operating systems.

3. How Operations Management Can Inform Human Resources Management

We have seen how OM research and practice might be enhanced by incorporating previously-overlooked “human factors.” The implications of OM for HRM and behavioral research in organizations are equally profound. In this section we will describe implications for HRM research that reflect insights from and integration with OM.

The main way in which OM can inform HRM is by providing greater completeness and precision regarding work context. The effectiveness of initiatives at the interface of HRM and OM, such as cross-training, teams and group-based pay, depend on context. This is widely recognized in HRM research, but better understanding and use of OM principles can greatly enhance the contextual relevance and sophistication of HRM.

3.1 Research Studies at the HRM-OM Interface

Analogously to Section 2, this section describes a number of specific research studies to illustrate the power of integrating HRM and OM. For each area we cite an HRM insight and then present an OM perspective that might provide context to enrich or alter the original insight.

HRM Strategy Inside the “Black Box”

HRM writers today routinely note the value of “getting inside the black box” between HRM investments/practices and organization-level outcomes (e.g., Dyer and Shafer 1999, Becker and Gerhart 1996, Chadwick and Cappelli 1999, McMahan, Virick and Wright 1999). Typical studies will describe an array of HRM practices, then choose particular individual behaviors or attitudes (e.g. turnover, job satisfaction or performance ratings), and examine if they are affected by the HRM practices, and finally examine whether both practices and behaviors/attitudes relate to organizational outcomes (e.g., Huselid 1995). To be sure, such studies illuminate the particular linkages they choose to focus on, but a process context from OM could provide a more specific logic that would enhance such research.

Boudreau and Ramstad (in press) have suggested replacing the metaphor of a “black-box” with a “bridge,” in which precise linking elements are specified and tested. A key element of this bridge is the connection between business processes and talent pools (e.g., Figure 2). OM provides an untapped reservoir of precision and insight about core business processes, offering a significant opportunity for HRM scholars to focus beyond the typical array of variables defined solely from the HRM perspective.

HRM: Organizations that report using certain HRM practices are more likely to have employees with more positive attitudes or lower turnover, and also to exhibit more positive financial outcomes.

OM: Financial outcomes are in part a result of optimization in key OM processes, which are likely to be affected by employee attitudes and turnover.

Proposed research:

- (1) Group organizations by the core OM processes they rely on to compete (e.g., low-inventory, team-build, server pooling). Determine which processes are most enhanced by low turnover, employee longevity and learning.

- (2) Analyze whether incorporating the key OM processes improves the predictive power of HRM practices, turnover, and attitudes on financial outcomes.
- (3) Add OM-based process outcomes (e.g., levels of WIP, bottlenecks) to the list of variables measured in strategic HRM research.

Goal-setting

The effects of goals on performance is one of the most robust and widely-researched areas in behavioral research (Knight, Curham and Locke 2001, Locke 1984, 1982), suggesting that hard, specific goals are optimum for motivation, and describing the processes through which individuals both accept externally-suggested goals and also how they set their own internally-established goals. Several of the examples in Section 2 suggest that different OM designs create different information and signals from the workplace or co-workers.

HRM: Hard and specific goals often induce greater individual performance than general “do your best” goals.

OM: Performance with regard to certain goals matters more than others. For example, in a low-WIP system, achieving goals for individual production speed may be less important than smoothing production variations that may cause bottlenecks. In a pooled-server setting, achieving a goal of proficiency on a particular task may be less important than properly switching tasks when required.

Proposed research: Compare process performance and individual worker behavior under conditions of hard, specific goals, based on: (1) overall group output, (2) individual task performance, (3) OM-informed goals that reflect the key process parameters.

Training

Traditional training research has revealed significant insights about necessary conditions to create learning (e.g., self-efficacy), to transfer and use learning at work, and the relative effects of different training activities, such as experiential, simulation, and expository (Goldstein 2002, Noe 2002). OM models can suggest specific contextual factors that affect these traditional training questions. Training research can help us understand how to build knowledge that will be applied, and OM can suggest where knowledge is most effectively applied.

HRM: Training is more effective when individuals perceive that they can succeed (self-efficacy) and when they understand and have the opportunity to apply their training to the workplace (transfer).

OM: Cross-training should be targeted to tasks that benefit optimally from worker task-sharing. For example, training “in a loop” (each worker is trained on two skills so that each skill is shared by a pair of workers) is the mathematically optimal way to gain the maximum ability for workers to share tasks, with the minimum training cost.

Proposed research: Compare training transfer levels and process effectiveness under traditional approaches that emphasize general levels of self-efficacy and transfer, to approaches where self-efficacy and transfer are targeted to the optimum training uses. For example, instruct workers in the optimum operational conditions to share tasks and examine if this enhances their effectiveness in transferring training, and their job performance.

HRM: Training costs and benefits are calculated as the subjective frequency of applying the training, and subjective estimates of the dollar value of improved individual worker performance (Morrow, Jarrett and Rupinsky 1997).

OM: Training has its greatest effect in tasks that occur with great frequency or in situations where task-sharing is most valuable. For example, call-center designs frequently allow predicting which task elements will arise for a given call and when task-sharing can optimally alleviate bottlenecks.

Proposed research: Incorporate OM predictions of task frequency and task-sharing impact into estimates of training return-on-investment. Compare subjective cost-benefit estimates to those that are informed by more precise OM principles.

Attraction and Retention

Decades of research in HRM and I/O psychology suggests a connection between worker attitudes toward their job and their likelihood of leaving. Research on “great places to work” (Levering and Moskowitz 2002) suggests that the opportunity for learning is a key factor in employee satisfaction and in attracting and retaining employees. Thus, it may be prudent to train workers broadly, as way to attract and retain them. However, OM models can show where the probability of any given worker actually using certain skills may be extremely low. Cross-training on infrequently-used skills may engender more frustration than satisfaction.

HRM: Workers report being more satisfied and attracted to organizations that provide learning opportunities, so those that provide more training should have lower turnover and higher productivity.

OM: Cross-training carried beyond a certain point results in workers trained in skills that OM models predict will be seldom used.

Proposed research: Incorporate OM predictions about the frequency of skill use into research on the impact of training on employee attraction, satisfaction and retention. Are seldom-used skills less effective as inducements and satisfiers?

High-Performance Work Systems and Line of Sight

High-performance workplace research (Appelbaum and Batt 1993, Ichniowski and Shaw 1999) suggests the value of team-building, empowerment and other “bundles” of HRM practices, often by measuring the production-level effects of those interventions (e.g., scrap, quality, production speed, etc.). It is a common finding that teams consisting of production designers, production workers and supervisors are associated with enhanced manufacturing and operations performance. Perhaps these associations reflect workers’ increased opportunity to recognize and articulate production issues and act on them (Salem, Lazarus and Cullen 1992). However, we know little about whether workers actually recognize the most pivotal elements of the production process, nor if they understand the operations principles on which such processes are designed.

“Line of sight,” or accurate perceptions about the link between actions, performance and rewards, is a relevant component of motivation and effectiveness in these situations. Boswell (2000) suggested that how accurately employees understand how their actions link to organizational goals also affects their attitudes and intentions to stay. A pervasive assumption in much of the “total quality” and “worker empowerment” literature is that those closest to the operation (often the workers carrying out the process) know the key productivity issues and opportunities for improvement (Flaherty 2001), and that by giving workers the discretion to make decisions, those improvements can be achieved. For example, the former production-line worker who is empowered to monitor a computer display depicting the entire steel production

line may now see the same data on which the OM optimization, design and diagnostic principles are based (e.g., speed, bottlenecks, variation in throughput, work-in-process inventory levels). Perhaps workers naturally identify where their behavior can make the most difference. A similar effect might occur when workers who formerly only carried out production tasks are now placed on design teams that include operations engineers, managers, supervisors, and co-workers that span the entire production process.

OM models provide a very precise description of exactly what workers should know or figure out in order to optimize the process. Do workers indeed generate mental models that accurately reflect OM principles simply by working in these systems? Can they be assisted by providing them with better summaries of the underlying OM theories and mathematics? Without such assistance, do such worker-involvement initiatives have their effects mainly due to enhanced (but still sometimes misguided) worker motivation that could be improved using OM principles?

HRM: High-performance work systems are associated with greater teamwork and empowerment, and with improvements in production-level process outcomes. This may be due in part to enhanced discretion and knowledge among those “closest” to the process.

OM: There are specific process-improvement principles that create the greatest impact on production-level outcomes. Workers empowered with knowledge of these principles may direct their discretion and knowledge more effectively.

Proposed research: Use OM principles to analyze the mental models of workers involved in high-performance work systems. Examine how closely these mental models reflect OM principles under conditions of assistance and no assistance. Compare empowered teams who are informed about OM principles to those who are not, in terms of their effect on production-level outcomes.

Compensation

Compensation research suggests that providing higher average rewards can enhance retention and attraction, provide a higher-quality workforce, and thus enhance the probability that when skills are used, they will be applied proficiently (Milkovich and Newman 2002). Such

research generally analyzes compensation in terms pay levels and contingencies in jobs or pay grades, or pay for certain skills and knowledge. OM models may allow much more precise design of optimal compensation premiums for skills and behaviors, considering the operational situations in which they occur. It may be possible actually to link proficiency levels with resulting service and manufacturing outcomes (in essence the shadow price of proficiency) and thus calculate the expected value they can create. Such models require not only OM principles, but must incorporate the effects of rewards on attraction and turnover, as a function of different performance levels (Boudreau, Sturman, Trevor and Gerhart, 1999).

HRM: Pay levels and pay based on specific skills or behaviors can increase the quality of the workforce and the level of skills or behaviors exhibited by individuals.

OM: Because worker knowledge and behaviors occur within production systems, OM models can identify the “shadow price” of proficiency differences, in crucial skills or behaviors.

Proposed research: Use OM principles to calculate the shadow price of pivotal employee behaviors or skills. Construct compensation and reward contingencies that reflect these shadow prices and examine resulting worker behaviors, worker attitudes toward pay equity and effectiveness, and overall system performance.

3.2 Systemic Changes in Our Approaches to HRM and Behavioral Research

Finally, as we consider how HRM can benefit from increased understanding of OM, several systemic themes emerge that suggest new directions or emphasis in future HRM research.

HRM Optimization, Not Simply “Maximization”

A fundamental difference between the approach of OM and HRM is that OM typically strives to develop frameworks that suggest optimal solutions, while behavioral research typically develops frameworks to explain how to enhance or maximize it. For example, typical research on employee selection focuses on maximizing correlations between selection system scores and job performance. However, some approaches identify optimum combinations of test validity, applicant pool size and other factors, designed to produce a desired number or level of

qualifications among new hires (DeCorte, 1998a, 1998b). Undoubtedly, there is great potential for considering optimization in other areas of the HRM field.

HRM Variables and Models Can Be More Granular and Predictive

A great deal of the criterion variance in behavioral and HR studies is unexplained, even when effects are statistically significant. Typical HRM criteria reflect broad individual behaviors, performance ratings, or high-level outcomes such as manufacturing or service output, or sales (Katzell and Austin 1992, Spector 2000). Incorporating OM principles would produce much more precise and granular criteria, and perhaps enhance the predictive power of such research. For example, workers with greater cognitive ability or conscientiousness seem to receive higher performance ratings (Bobko 1999, Schmidt 2001) organizations that use cognitive ability tests appear to be more profitable (Terpstra and Rozell 1993), and production lines that invest in worker training and empowerment appear to have higher productivity and quality (Batt 1999, Ichniowski et al. 1997, Ichniowski and Shaw 1999). Yet, we know very little about which individual behaviors are enhanced by these investments, nor whether those behaviors are the ones that OM models have identified as having the greatest effect on the manufacturing or service operations contexts. This applies to most HRM areas, including selection, training, goal setting, justice, equity, compensation, and motivation.

Thus, HRM research could explain more variance in organizational outcomes by acknowledging these contextual factors, and incorporating them into models and empirical studies. Using OM principles allows guiding this granularity, rather than simply choosing criteria based on convenience or out of context.

HRM Evolves from “Program-Delivery” to “Decision-Based Investments”

The OM-HRM interface has significant implications for the way HRM programs are chosen, targeted and evaluated. Traditionally, when HRM managers or researchers wish to estimate or demonstrate the value of HRM programs, they measure the effects of a program in terms of correlation coefficients, standardized regression weights, or *t*-values, all of which are in standard-score units, which cannot readily weighed against dollar-valued program costs. These

effect sizes must be translated into dollar values, and translation methods have been debated for decades (Boudreau and Ramstad, in press). The translation approaches virtually all require a subjective judgment about the dollar value of differences in these individual attributes (e.g., the dollar value of the difference between a person who performs better than 50% of the workers versus one who performs better than only the bottom 15%). Often, this question is posed to operations managers. There is no consensus on an accepted translation approach, nor any evidence of the accuracy of these judgments. Our observations in this article suggest a more decision-focused approach that would examine how individual differences affect key pivotal business processes, and trace the monetary implications through those processes. The shift from HRM as program delivery and evaluation to HRM as decision-based investment requires a logical system to identify the talent pivot points. In manufacturing and service operations, OM models can help to provide this logical system.

4. Toward an Integrated OM/HRM Framework

In the previous sections we have offered a host of academic and industry examples that illustrate some of the powerful connections between OM and HRM. At a fundamental level, the two cannot exist without one another. OM policies can only be carried out by people and HRM policies are only effective if they foster people doing organization-critical tasks (i.e., operations). And the connection is not just theoretical. As many of our industry stories suggest, considering HRM in formulating OM policy, and vice versa, can be good management practice.

But observing philosophical connections or implementation synergies is not the same as providing an integrated OM/HRM framework. Our review of the two fields indicates a great many gaps in our understanding of the links between them. Some of these are likely to be filled by “research as usual,” but many are not. Only via a conscious effort to explore the interface between OM and HRM will we be able to provide a framework to support better, more integrated management policies.

Research into an integrated OM/HRM framework will not be simple or linear. We are simply not close enough to such a system to attack the problem directly. Several very different

paths must be pursued to build up the body of knowledge needed to construct a unified understanding. In the following, we identify the basic classes of research that are needed and discuss the challenges and opportunities in each.

An Illustration: The Debate Over “Lean” versus “Empowered Teams”

Consider recent OM research results on collaborative work environments (Van Oyen et al. 2001). They studied a serial production system in which they assumed that (a) workers are identical, (b) workers can collaborate on tasks, (c) process times are inversely proportional to the number of people assigned to the task, and (d) there is no cost or time delay to switch between tasks. They showed that average WIP and cycle time are minimized if all workers collaborate as a team, taking jobs successively from the queue at the front of the line and processing them through the entire line.

One might be tempted to conclude from this result that environments in which collaboration is efficient (e.g., workers don't get in each other's way when working simultaneously on a task) are good candidates for team build strategies. Indeed, sometimes they are. For example, Van Oyen et al. cite their experience with Elgin Digital Colorgraphics (EDCG), a pre-media printing process of R.R. Donnelley and Sons. In this system, most operations are conducted on workstations and jobs can be divided among workers by assigning pages to individuals. Teams of workers followed jobs through almost the entire process. In addition to realizing the efficiency benefits predicted by the model, this protocol also ensured that the customer would have a single point of contact for a job throughout the system, facilitating changes and helping to ensure quality.

But this kind of team build strategy doesn't always work. Most famously, Volvo opened its Uddevalla plant in 1988 with a widely touted autonomous team approach for assembling an automobile. Intended to “humanize” assembly line work in order to improve motivation and reduce absenteeism and turnover, the plant never achieved productivity levels comparable to traditional plants. It was closed in 1993 (Moore 1992, Prokesch 1991, Rehder 1991, Sandberg 1993).

In a more recent case, one of the authors observed two plants owned by Federal Signal. One produced sewer-cleaning trucks using a team assembly system; the other produced street sweeping trucks on a progressive assembly line. The team assembly system had been adopted to facilitate flexibility—the firm would make almost anything the customer asked for. But because trucks were built in bays, there was little pacing pressure. Moreover, because of the wide range of tasks involved, workers spent considerable time figuring out how to do things. As a result, even though the two products were similar in complexity and customization, the progressive assembly line had much higher productivity, better quality and superior customer service. It didn't take long for a new management team to decide to drop team assembly in favor of an assembly line.

What we see in comparing EDCG and Federal Signal, illustrates the value of our suggestion that we build an explicit logic combining and integrating what OM tells us about business processes, the resulting talent issues, and the HRM implications. There is a small, but vocal “anti-lean” faction that cites the empowered team approach as more humane approach to work, which will ultimately replace highly specialized, standardized work procedures associated with lean manufacturing. Yet, these examples suggest that the motivational benefits of team build have not outweighed the efficiency benefits of specialization in most manufacturing environments. If so, then we just have an “OM beats HRM” conclusion with regard to lean manufacturing. We propose that there is something richer here. The choices in work design aren't only Taylorism (do one tiny thing) or Team Build (do everything). There are many options in between.

The OM model shows where to look for the “pivot points” that may be affected by talent. In determining whether team-build is superior to progressive-build, talent will “move the needle” most at the points where task collaboration and handoffs are most important. It is these transition points that will move the needle (not simply the overall individual productivity levels,

average team ability to do various tasks, etc.). So, we look for the talent pools and human characteristics that most affect these transition points.

4.1 Improved OM Models

In Section 2 we provided a list of HR variables that are typically omitted from OM models. A good start toward a more sophisticated generation of OM models would be systematic research into how to incorporate these issues into classical models of operations problems. To illustrate this, let us reconsider the examples of EGDC and Federal Signal. Table 1 contrasts those examples in terms of the COMU framework we have introduced. Note how different these two cases are on each of the dimensions. The granularity provided by the COMU framework reveals opportunities that are obscured in a debate simply framed as “lean versus team.”

Table 1
HRM Variables Affect Outcomes Differently Based on Context

Example	Capability	Opportunity	Motivation	Understanding
EDCG	Similar skill requirements make workers more fungible without high costs of very specialized training.	Modular design (pages) easily accomplished at different workstations allows work transfer and handoffs to be made easily and often	Communication with customer translates easily into decisions to change pacing. Valued worker outcomes are clearly linked to good decisions about handoffs and pacing	Similarity of tasks and simple modular and transferable design make it easier for workers to see how their part affects the whole.
Federal Signal	Skill requirements vary significantly throughout the production process, making fungibility very costly or difficult.	Requirement that assembly occur in bays makes task transferability difficult and constrained or extremely costly.	Bay-based assembly means that worker decisions about pacing have less effect on outcomes. It also inhibits between-team work-pace comparison (a motivational factor). Variability in skill requirements and abilities means that workers wait for the most-skilled worker rather than do a task they are poor at.	Task complexity, both in skills and product-movement logistics, makes it harder for workers to link their behaviors to the ultimate outcome.

An incident that occurred during the writing of this paper provides another example. One of the authors had a discussion with a colleague about why pull systems work. They agreed that a fundamental property of pull systems is that they delay releases based on system status, disagreed on whether delaying releases would necessarily delay completions. A sample path argument “proves” that later releases could never lead to earlier completions, but the proof assumes that process times are unaffected by the pull system. In real-world systems this may be untrue. Shorter queues might facilitate detection of quality problems and lead to less rework. Greater communication between stations could help operators eliminate mistakes. The more-obvious need for smooth flow in a low-WIP system might lead to more manufacturable product designs. These and other behaviors that might be induced by use of a pull system are all dependent on how the people involved react. Far from being minor details, these mechanisms for reshaping a production environment may explain some of the most important benefits.

The above example is an all-too-common case of a standard OM modeling technique that fails to capture something fundamental to an operating system. In the search for mathematical rigor, such models can yield insights that are incomplete or misleading. The OM literature is replete with such models.

4.2 Improved HRM Frameworks

To address situations like those at EDGC and Federal Signal we believe that an extended HRM model should consider not simply the proficiency of each individual worker, nor even simply the proportion of workers who can do all of the tasks involved in the potential task-sharing design. Rather, HRM can consider the costs of adding worker fungibility, the likely motivation of workers to make efficient and effective hand-offs, and the design of the work and production process as it either facilitates or constrains the pivotal behavior – handing off work at low cost and with high quality.

OM and HRM managers would consider together the cost function involved in building optimal levels of fungibility, including not only skills but also any changes in reward systems, communications and process design needed to affect Capability, Opportunity, Motivation and

Understanding. Integrating these costs into standard OM models will enhance the ability to find an optimum design, and more clearly accounts for the talent issues.

As the processes are implemented, the enhanced model we propose suggests a very different role for HRM. Rather than simply delivering training or compensation programs, the HR manager now assesses worker effectiveness at making handoffs, their overall understanding of how their individual actions relate to the outcome, their reactions and decisions based on customer pacing input, etc. The result is likely to be a more integrated or “bundled” set of HRM programs and investments that are more clearly linked to the production pivot points.

These new HRM outputs would provide OM managers with data to deal explicitly with formerly hidden issues such as the cost function for worker fungibility, process design tradeoffs in facilitating handoffs, process designs that allow workers to link their behaviors to the ultimate objective, process designs that allow workers to translate customer pacing information into good decisions, and the cost-productivity tradeoffs that are associated with all of these design elements.

4.3 Behavioral Research

A serious impediment to including human behavior in OM models is the simple fact that we do not know how humans behave in specific operating environments. When do long queues motivate faster work? When does low WIP promote better problem solving? When does broader product responsibility lead to higher quality levels? The list of unanswered questions that are central to the choice of effective OM policies is very long. Indeed, because research into behavioral issues that underlie modeling of operations systems is just getting started, we do not even have a comprehensive list of the questions.

In Sections 2 and 3 we suggested research to address specific areas where human issues are likely to be decisive in understanding the performance of OM policies. While this list is still preliminary, it gives a sense of the style of research that is needed. We can classify the questions that require behavioral research into categories: Factors that affect (a) worker speed,

(b) worker memory, (c) turnover, (d) ability to learn new tasks, (e) quality of work, (f) communication between workers, and (g) problem solving by workers.

The above examples suggest areas where insights into human behavior can directly inform OM models. A complementary set of questions reflects how attention to OM principles can inform HRM research, as we have noted.

- What specific behavioral issues make the most difference to key organizational processes?
- What are the “mental models” that workers and their supervisors use to make decisions about where to direct their efforts? Do those mental models reflect the OM principles that actually describe process optimization? How are they affected by HRM practices such as training, performance assessment and rewards?
- Is “more is better” always true when it comes to HRM investments, or are there optimal levels of those investments that reflect the operational context?

Behavioral research may be the key to achieving an OM/HRM framework. Researchers in OM may gradually incorporate better representations of humans in their models. Researchers in HRM may enhance their paradigms with more specificity of operating context. But behavioral research directed at improving models of OM situations is a scholarly path with little precedent. The major OM journals have little history of publishing this type of research. The applied behavioral science journals are seldom read by OM researchers. The lack of senior faculty with backgrounds in this style of research presents a challenge to junior faculty.

Much of the behavioral research discussed above can be done in experimental settings. However, to validate an OM/HRM framework also requires empirical study of the behavior of actual system performance at a macro level. Controlled behavioral experiments are essential to provide building blocks. But real-world systems are always more complex than experiments. So, to find out how policies really perform, we need to evaluate their performance in industrial settings.

Do teams enhance performance in terms of both quality and productivity? What kind of teams? (Some excellent research has been done to date. See Bailey 1999, Banker et al. 2001,

and Banker et al. 2001 e.g.) Are pull systems profitable? Does cross-training reduce or increase turnover? Has the lean manufacturing movement had a demonstrable impact on the American economy? Big questions like these can only be addressed via careful empirical analysis of large-scale systems.

Empirical research is more prevalent than behavioral research in the OM literature. But it is hardly commonplace. Part of the difficulty is that conclusions based on statistical analysis of noisy data are necessarily less crisp than those based on detailed mathematical models. As a result, modeling researchers are prone to regarding such research as less than rigorous. But this need not be the case. Given carefully constructed experiments and appropriate statistics, such analysis can yield important insights into some of the biggest questions associated with the OM/HRM interface.

An example of an empirical study of the overall effectiveness of policies on a large scale is the work of Rajagopalan and Malhotra (2001). Using Census Bureau data, the authors studied trends in raw materials, work-in-process and finished goods inventories in 20 manufacturing sectors from 1961 to 1994. They found that while inventories in all categories trended downward over this interval, but did not do so at a higher rate after 1980, suggesting that the JIT and lean manufacturing movements may not have had as pronounced an effect as popularly believed. Of course, inventories are confounded with many factors, including the business cycle, so it is difficult to draw sharp conclusions from this type of study. Still, if we are answering the questions of which integrated OM/HRM policies are effective and which are not, we will ultimately have to make use of this style of empirical research.

5.0 Conclusions

In this paper, we have presented a number of views.

- OM and HRM are intimately dependent on one another as management functions in practice.
- Traditional OM research has omitted and/or simplified human behavior, sometimes to the point where it has caused the resulting models to yield results that are not only quantitatively inaccurate, but are also qualitatively misleading.
- Traditional HRM research has often focused on important behavioral issues, such as motivation, teamwork and learning, in isolation from the specific operations context in which people work. This undermines the predictive value of the paradigms and makes the results from such research difficult to incorporate into OM models and work processes.
- To achieve an integrated OR/HRM framework, with which to evaluate policies in both fields, research is needed in the following areas:
 1. Improved representation of human behavior in quantitative OM models,
 2. Incorporation of operations contexts into HRM frameworks and research,
 3. Behavioral research into understanding behavior of human beings in specific operating systems
 4. Empirical research of the impacts and effectiveness of OM and HRM policies

Researchers are just beginning to address these issues. We take this as a very hopeful sign that we are on the verge of a new era of OM/HRM integration. However, as we have noted here, there are a great many research challenges that need to be addressed before the synergies of these fields, in research and practice, are realized.

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