THE IMPACT OF OPERATIONAL FAILURES ON HOSPITAL NURSES AND THEIR PATIENTS

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ABSTRACT

Operational failures in healthcare can hinder employees, potentially decreasing both productivity and quality of care. At the same time, regulatory agencies, industry experts, and consumers increasing demand that health care organizations learn from prior failures to prevent recurrence. Building on the notion that learning from operational failures requires an accurate understanding of their nature, this paper reports on an in-depth study of operational failures encountered by hospital nurses. Data analysis suggests that in this context (1) most operational failures stem from breakdowns in the supply of materials and information across organizational boundaries and (2) employees quickly compensate for most failures. We propose that these two conditions—lack of control of processes that create failures and the ease with which employees restore functioning—make it difficult for organizations to recognize these incidents as learning opportunities, and if they do, to capitalize on the opportunity. This has an important implication for efforts to generate organizational learning and improvement from employees’ experiences with failures. Highly interdependent front-line workers do not control organizational processes responsible for the majority of failures they encounter and have a difficult task convincing powerful associates that these obstacles warrant solution efforts, making it likely operational failures will persist.

Keywords: Operational failures, Organizational learning, Service organizations
1. Introduction

Operational failures occur with such regularity in complex service organizations that many scholars deem them inevitable. In particular, failures trouble healthcare institutions, as evidenced by a recent report that estimates medical accidents kill more people each year than do motor vehicle accidents, breast cancer, or AIDS (Kohn et al., 2000). Furthermore, failures intensify two main challenges facing organizations: escalating costs and labor shortages.

Operational failures—disruptions or errors in the supply of necessary materials or information to employees—have received considerable research attention for several reasons. They can frustrate and hinder employees, decreasing individual and organizational performance. At the same time, they illuminate improvement opportunities, potentially leading to organizational learning and increased productivity. Despite theoretical appeal, however, evidence linking operational failures, individual performance, and organizational improvement has been inconclusive (see Peters et al., 1985). In general, laboratory studies provide support for a relationship between constraints and performance whereas field studies do not. Research also suggests that most organizations find it difficult to learn from failures (e.g. Carroll et al., 2003). Thus, it appears that operational failures fall short of their potential to influence both performance and improvement.

To begin to unravel this puzzle, we conducted ethnographic research on hospital nursing units. Our research questions were as follows: What is the nature of operational failures encountered by hospital nurses? And, what effect do these failures have on employees and patients? In contrast to prior studies that relied on employee and manager
perceptions of failures collected via surveys, we used observational data to quantify the nature and impact of operational failures. This paper thus sheds important, new light on the relationship between failures, performance, and organizational learning.

Our study yielded a database of 194 operational failures. We found that the majority results from breakdowns in organizational systems, such as medication and material delivery, and therefore spanned organizational boundaries. In addition, most were systematic, chronic problems (Juran and Gyrna, 1980; Leonard and Miller, 1989), rather than idiosyncratic errors. On average, 9% of nurses’ time (44 minutes per eight-hour shift) was wasted on failure resolution activities such as calling the pharmacy for medications that should have been—but were not—in a patient’s medication drawer; tracking down a thermometer; or trying to find out which doctor was covering a patient. In addition, operational failures interrupted nurses’ concentration, delayed patient care, wasted hospital resources and put patients at risk.

Despite their connection to productivity and quality of care, we propose that the full costs of operational failures remain hidden, making it difficult for organizations to recognize and capitalize on the learning opportunities posed by operational failures. First, the embedded—and conditional—nature of failures makes it hard to convey potential impacts to those who control resources necessary for removing underlying causes. Second, errors often are not viewed as learning opportunities because employees can work around them quickly and they result from established work routines and as such, suffer from organizational inertia (Leonard-Barton, 1992; Nelson and Winter, 1982).
The data presented in this paper suggest that to learn from failures in daily work routines, organizations need methods for solving failures that reflect demands of the work environment and the boundary-spanning nature of problems and errors encountered by front line workers. We propose that efforts to reduce operational failures should focus on (1) designing work systems that facilitate coordination and communication between dependent groups, and (2) developing problem solving procedures that enable employees to effectively address failures that stem from other groups. Furthermore, the difficulty of resolving cross-boundary problems suggests that error-proofing daily activities, such as poka-yoke devices (Chase and Stewart, 1994), to prevent failures from being passed on to another department are especially valuable in this context.

2. Previous research on operational failures

Despite the ideal that workers perform their tasks correctly the first time and provide error-free service (Bowen and Lawler, 1995; Hart et al., 1990; Price, 1990; Stewart and Chase, 1999), operational failures occur in most organizations. In fact, given the high level of human interaction in service delivery, researchers claim that problems and human errors leading to failures are inevitable (Bowen and Lawler, 1995; Edmondson, 1996; Johnston, 2001; Levesque and McDougall, 2000; Schweikhart et al., 1993).

Operational failures can negatively impact organizational performance. Large scale individual failures are rare, but can cause significant damage, such as fatal or disabling medical errors (Kohn et al., 2000), scoring errors on high-stakes educational tests (Henriques and Steinberg, 2001), or catastrophic equipment failures (Vaughan,
More common are smaller incidents that nonetheless result in cycles of failure that can prevent employees from providing service in the expected time frame and quality level (Heskett et al., 1997). When failures occur, service recovery—action taken by a service provider after a customer fails to receive the desired service (Gronroos, 1988)—determines customer satisfaction and retention (Bitner et al., 1990; Hart et al., 1990; Michel, 2001; Miller et al., 2000; Smith et al., 1999), which in turn drive firm profitability (Bowen and Lawler, 1995). Similarly, research suggests that operational failures affecting internal customers (employees who receive goods or services from other employees) can also negatively impact performance (Auty and Long, 1999; Bowen and Johnston, 1999).

Information from operational failures can catalyze change and improvement (Sitkin, 1992). Failures are usually signals of underlying system flaws, or latent errors, that can reappear with more serious consequences (Reason, 1990). Consequently, researchers advocate putting systems in place to capture information about previous failures to prevent recurrence (Hart et al., 1990, Reichheld, 1996). In addition, organizations that systematically focus on preventing and responding to operational failures can achieve high levels of reliability, even in inherently risky environments such as nuclear powered air-craft carriers, nuclear power plants, and the air traffic control system (Roberts, 1990; Weick et al., 1999).

Learning from operational failures requires a thorough understanding of their nature (Stewart and Chase, 1999). Prior research suggests that operational failures stem from many sources including from human error (Stewart and Chase, 1999), equipment problems (Perrow, 1984), deviation from expected processes (Reason, 1990), and
miscommunications between customers and suppliers (Michel, 2001). For example, research on situational constraints provides a comprehensive description of types of constraints encountered by workers. The most frequent categories include job-related information; tools and equipment; materials and supplies; budgetary support; required services and help from others; task preparation through education, training, and experience; time availability; physical aspects of the work environment; and scheduling of activities (Peters et al., 1985).

Although research highlights the existence of operational failures, their impact on employee performance is less conclusive. Peters and his colleagues found, contrary to their expectations, that workers reported experiencing only low to moderate levels of constraints (Peters et al., 1985). Constraints had a negative impact on job performance in laboratory settings, but were not consistently associated with decreased performance in actual job environments (Peters et al., 1985). One reason why constraints may not be reflected in performance is that over time workers devise routines to compensate for obstacles (Nelson and Winter, 1982). This suggests that the connection between worker autonomy and job satisfaction may in part be due to their ability to resolve or avoid failures. For example, Tesluk and Mathieu (1999) found that road repair crews who performed preventive maintenance in anticipation of frequently occurring machinery problems did not report as many problems with equipment as crews with less active problem-management tactics. Similarly, other studies have shown that managers underestimate the existence and impact of constraints in comparison to workers (Brown and Mitchell, 1994).
3. Research methodology

3.1 Research context

Hospital nursing units provide an especially fruitful research context in which to research operational failures. Task interdependence and uncertainty characterize this work (Glouberman and Mintzberg, 2001), increasing the likelihood that failures will occur. Task interdependence (Wageman, 1995) implies that nurses’ ability to perform their duties depends on a wide variety of other professionals—doctors, pharmacists, laboratory technicians, food service workers, housekeepers, secretaries, and nurses’ aids—completing their tasks properly. Further, the inherent uncertainty in providing care to many patients, each with a unique set of health conditions and response to treatment, makes it difficult to predict which services and materials will be needed for nursing care. These two conditions—reliance on numerous other departments and unpredictability—make it likely that nurses will encounter situations when they do not have all the materials, information, or services to treat patients.

Operational failures accentuate the challenges facing the healthcare industry. For example, many medications and treatments are most effective when administered within specific time frames; failures obstruct workers from conforming to these parameters, potentially decreasing quality of care. Research also suggests that the majority of catastrophic accidents stem from tragic interactions among several slips and errors in the system of delivery rather than from one dominant failure (Chassin and Becher, 2002; Reason, 1990). In the worst cases, such errors can result in patient death, employee termination, and expensive lawsuits or out-of-court settlements. Even if patients are not killed by service failures, hospital administrators have reason to be concerned because
these obstacles hinder health care providers, whose time is both expensive and scarce. In addition to lost productivity, such work-related frustrations can contribute to employee turnover in an industry already plagued with shortages of skilled laborers (Buerhaus et al., 1999). In sum, operational failures have important implications for healthcare organizations, their workers, and their customers and thus nursing units provide an appropriate context for our research.

To our knowledge, few nursing studies have explicitly considered how operational failures impact nurses and their patients. Research has been conducted concerning sources of medication errors (e.g. Leape et al., 1995), but less attention has been paid to the larger set of failures that disrupt patient care without posing an immediate threat to patient safety. (For notable exceptions, see Eaton (2000) and Tillman (1997), who found that insufficient staffing and shortages of supplies, equipment, and medication cause nurse dissatisfaction and reduce quality of care.)

3.2 Data collection methods

To provide prescriptive advice about how to reduce occurrence of operational failures, it was necessary to first understand their fundamental nature (Mintzberg, 1989; Stewart and Chase, 1999). We used qualitative, hypothesis-generating methods, which are appropriate when the topic of interest is not well understood (Eaton, 2000). Our choice of methods was consistent with the advice of grounded theorists (Kuhn, 1970; Strauss and Corbin, 1998; Yin, 1989) who emphasize the importance of gaining a solid base of observed events and descriptions of the observations as precursors for categorization and theory building.
The author, who is a management researcher with a background in quality engineering in manufacturing settings, spent 239 hours shadowing 26 different nurses at nine hospitals and recording detailed information about their work activities. Ten hospitals with reputations for excellent nursing care were selected for observation, but one facility declined to participate in the study. The hospitals were located in the United States and Ontario, Canada and varied in size, ownership, and teaching affiliation. The mean number of beds in participating hospitals was 206. Two hospitals had less than 100 beds, three had 100-200 beds, another three contained 200-300, and the largest possessed 433 beds. See Table 1 for a description of units observed.

The nurses observed typically were experienced employees who had worked for at least three years on their current unit—only two of the 26 nurses had been out of nursing school less than two years. Thus, the failures observed were not a result of nurse inexperience or unfamiliarity with hospital procedures. Participation was voluntary, and four out of 31 (13%) nurses declined.

The observation process entailed close shadowing of a nurse, including following him or her into patients’ rooms after obtaining consent. Observations ranged from two to twelve hours in duration and included all three shifts and weekends to capture variation in nursing tasks and availability of resources. The observation style was observer-as-participant (Gold, 1969); in 19 out of the 35 (54%) observation sessions the author
performed small tasks such as changing beds, getting water for patients, and helping nurses lift and move patients.

Notes were recorded in a field journal regarding the duration, content, and location of nurses’ activities. For ten nurses from five hospitals, notes were taken on a minute-by-minute basis for an entire shift. Conducting time studies for complete shifts was beneficial to quantify the impact that failures had on nurses’ productivity because failures could cause multiple, discontinuous interruptions that might be missed with sampling techniques. In addition, work sampling techniques are not suitable for estimating duration of work activities, only relative frequencies (Burke et al., 2000). Similarly, full shift observation increased the reliability of data on the impact that failures had on patients by increasing the chances that all consequences of incidents were recorded.

After collecting observation data, the author conducted 60-minute interviews with thirteen nurses, ten of whom had been observed. The semi-structured interview protocol was developed after analyzing the observation data and was designed to increase understanding of how failures affected nurses’ productivity, their feelings about their work, and patient care. Four interviews were conducted in person, and nine were telephone interviews. All interviews were tape recorded and transcribed by the author.

3.3 Data analysis methods

We used an iterative, grounded theory approach to create a database of failures encountered by nurses. At the outset, we defined a “failure” as a problem in the supply of information, material, equipment, or services that interrupted the nurse’s work. This
definition, similar to the notion of situational constraints in the human resource literature (Peters and O'Connor, 1980), was not conducive to achieving satisfactory levels of interrater reliability because it required subjective opinion about whether a situation hindered the nurse enough to be considered a failure. In addition, data gathered using this definition had low internal validity. We observed nursing work to be highly fragmented and at times chaotic. However, the database of failures generated with this definition did not capture either of these characteristics. Also, using this definition we did not identify situations that nurses themselves described as problems during subsequent interviews. For instance, we had observed a doctor interrupt a nurse to inform her that he had just written an order for an antibiotic. Originally, we did not consider this as a failure, but instead a sign of good communication because it ensured that the order was not missed or misunderstood. However, during our interviews, one nurse commented that interruptions from doctors—especially for unnecessary reasons such as informing her of a newly written order—were frustrating and demeaning because she knew to look in the order book for new orders and would do so when the task at hand was completed.

The second attempt, which proved successful for interrater reliability and coding consistency between interview and observation data, considered whether there were failures in work system design that resulted in the worker being less effective than he or she otherwise might have been. Failures can stem from the worker’s own actions or the actions of others that supply workers with necessary materials, information, or services. Two general categories of work system failures emerged: problems and errors.
3.4.1 Coding types of failures: problems and errors

We define a “problem” as a disruption in ability to execute a prescribed task. There are two general types of problems: (1) something the worker needs is unavailable in the time, location, condition, or quantity desired and hence, the task cannot be executed as planned or (2) something is present that should not be, interfering with the designated task. Examples of problems include missing medications and doctors interrupting nurses to inform them that they wrote an order.

We define a “system error” as the execution of a task that is subsequently determined to be unnecessary or wrong. System errors are not necessarily medical errors, which are failures to administer a treatment as ordered, but instead are errors in the flow of work. This definition is broader than medical errors because it considers situations where the unnecessary procedure or task is benign, but wastes hospital resources. Examples of system errors include preparing a patient for transfer and then finding out that the transfer is cancelled; and preparing a morning medication for a patient and then finding out from the physician during patient rounds that the medication is discontinued.

These two types of failures are distinct from each other. Problems occur when work systems do not function as expected. Workers are aware of these failures when they occur because they either interfere with completion of the current task or add an additional task to their workload. In contrast, errors occur when the system appears to be functioning as designed. Workers are not aware of system errors because these failures do not obstruct the flow of work. It is only after the fact that employees realize their efforts were unproductive.
3.4.2 Coding sources of failures

We further coded the source of failures depending on whether it arose from the nurse’s own work activity, the nursing unit’s activities, or groups outside of the nursing unit. Thus, the data captured the degree to which nurses could control the failures, ranging from those under the jurisdiction of the worker to those outside of his or her manager’s control—with the assumption that these sources require different solution methods.

3.4.3 Coding nurse and manager perception of failures

Finally, drawing on our observation data we coded for nurse and manager response to the incident as a failure. If nurses expressed displeasure or frustration with the situation, we took that as evidence that they considered the incident to be a service failure and may be motivated to resolve underlying causes. For example, one nurse commented that she thought it was a problem that she had to spend so much time looking for a thermometer and wondered why the hospital did not purchase more of them. When nurse response to the situation was of a routine nature, we interpreted that to mean that they perceived the incident as a normal part of nursing, not a failure and as such, would lack both recognition and motivation to improve the situation. For example, a nurse could not find milk of magnesia on her medicine cart and went immediately to another medicine cart, which had the medicine. She continued preparing her medications and commented to the observer that her cart just ran out, it was no big deal because there was some on the other cart and the pharmacy technician would be up soon to restock the carts anyway. Finally, if managers showed they were concerned about situations through their
actions or words, we assigned a code indicating managers perceived them as service failures. To illustrate, one manager helped a nurse resolve a discrepancy on the narcotic count sheet by rechecking the previous shift’s calculations. Of 194 failures, 84 (44%) were not treated as failures by either nurses or managers, 102 (52.6%) were treated as failures by nurses alone, and managers were directly involved with only eight (4%) of the situations.

3.4.4 Reliability of coding

To test reliability of the coding scheme, we performed two sets of analyses. First, the author and another person unaffiliated with the research project independently coded 41 excerpts as either a failure or not a failure. Second, we coded the sources of 20 different failures. Agreement between our ratings were evaluated using the kappa statistic, which is appropriate to use for interrater reliability when there are a fixed number of choices. Kappa accounts for the expected probability that codes will match because of random chance. A kappa value of 0 means that the amount of agreement is the same as would be expected by guessing randomly, a negative value is worse than chance, and a positive value is better than chance. The kappa value for whether an excerpt was or was not a failure was 0.81 (std. error 0.15), which is considered almost perfect agreement (Landis and Koch, 1977). We had complete agreement for failure type, yielding a kappa of 1.0. The high level of interrater reliability increased our confidence in the validity of the coding scheme and the reliability of having one person code the remaining transcripts.
4. Impact of work system failures

4.1. Measures of impact

Inductive analysis of observation and interview data related to effects of failures on nurses, patients, and hospitals suggested nine individual measures of failure impact, clustered in three groups. The first group related to the impact on nurses, such as the number of additional tasks performed by the nurse to resolve the failure; the number of minutes the nurse spent directly on resolving the failure (direct time); the number of minutes the nurse spent on activities indirectly related to the failure (indirect time); and the number of interruptions to the nurse’s work that were caused by the failure. The second group of measures related to impact on patients—a rating of risk to patient safety; the delay until the failure was resolved (direct delay); and the additional delay from failure resolution until task completion (indirect delay). The third group consisted of two measures of the overall impact to the organization—the number of people who were contacted to help with the failure; and a rating of tangible and intangible losses incurred by the hospital as a result of the failure.

After creating the nine measures, we used interview and observation data to create two subjective weighting scales—one for the severity of delayed tasks and another for the severity of interrupted tasks. Delay weights, a rating of the time-sensitive nature of the task, ranged from one (least time-sensitive) to four (most time-sensitive) and were determined inductively by observing how nurses prioritized their work. For example, nurses frequently postponed documentation tasks, which were given weighting of two. Bathing patients and attending to families’ questions were given weightings of three. Although nurses completed these duties promptly, they first performed tasks such as
medication administration, preparing patients for surgery or laboratory procedures, and participating in patient rounds, all of which were given ratings of four. Interruption weights were a measure of the severity of interrupting that type of task. They ranged from one (least interruption-sensitive) to four (most) and were generated from both interviews and observations. For example, during interviews nurses commented that they disliked being interrupted while providing direct care to a patient because it made the patient feel unimportant and at times uncomfortable, such as during a bath or dressing change. Therefore interruptions during direct patient care weighted as four.

Having established nine measures of impact and related weights, we then scored each of the 194 failures in our dataset on all of the measures. Weighted measures of direct and indirect delays were calculated by multiplying the number of minutes by the delay weight. Similarly, we calculated a weighted interruption weight by multiplying the number of interruptions by the interrupted task weight. For means, standard deviations, and ranges of all nine variables, see Table 2.

4.2 Severity index and principal components analysis

These nine measures were also used to create a composite index of failure impact. We followed the methodology described in MacDuffie (1995), converting the values (n=194) for each of the nine variables into z-scores, ranking the z-scores, and then additively combining the ranked scores to create an overall index of the total impact on
nurses, patients, and hospitals. Index scores were converted to ranks from 0 (lowest) to 100 (highest) for ease of interpretation.

4.3 Approximate cost of service failures

We approximated the cost of each failure by multiplying the nine impact measures by conservative estimates for average wage rate of a nurse, cost per day in a hospital, and cost per medical error. Our purpose in computing these figures is not to present them as actual costs, but instead to provide a sense of magnitude of failures described in this paper. In addition, they provide an estimate of potential benefits to be gained from removing work system failures. Total costs ranged from $0.33 to $2,177. See the Appendix for details.

5. Results

5.1 Impact of failures

5.1.1 Individual impact of failures

We observed a total of 194 failures, an average of one every 74 minutes, or 6.5 every eight-hour shift. At a median estimated cost of $117 per failure, on average approximately $95 per hour per nurse was lost to operational failures. Most failures appeared individually to be minor, a finding that corroborated earlier work on situational constraints (Peters et al., 1985). First, nurses did not spend much time per incident—50% of the failures required three minutes or less or the nurses’ time, and only sixteen (8.2%) took more than ten minutes to work around. Nurses typically performed one additional task, such as calling the pharmacy for a missing medication, with just 25 failures (12.9%)
requiring more than four additional tasks. Second, there was a concentration of low cost failures; 30% had an approximate cost of less than $15. Third, failures usually had a minor impact on patient care. For example, half of the failures delayed patient care by four minutes or less. Furthermore, operational failures, on average, caused patients some discomfort or inconvenience, but usually did not pose a major safety risk to patients. Thus, in general, failures were simple to work around and appeared to individually have minimal consequences for nurses and patients. However, there was variance in severity of individual failures with some having more serious implications for patients and nurses. To illustrate the scope of situations, we provide more detail below on low and high impact failures.

- 5.1.1.1 Low impact on all dimensions

Twelve (6%) of the failures were uncomplicated to resolve, did not reduce the efficiency of patient care and did not interact with other aspects of the nursing environment. The mean cost of these failures was $0.82. Most of these failures were trivial, such as having to spend an extra minute to find an empty laundry hamper, running out of hand soap in the dispenser outside a patient room, or doing a quick task for another nurse’s patient. On average, nurses spent two minutes resolving these failures, had to perform no or only one other task to resolve the situation (mean = 0.5), and often did not need to get anyone else involved (mean = 0.3). Efficiency of patient care was not affected; the failures did not result in any losses for the hospital, caused minimum delay to patient care (mean = 0.25 minutes), and nurses did not spend time on the problem after it was resolved. Similarly, these failures did not interact with other conditions to
interrupt nurses or delay care. Nurses were able to complete their tasks once the system was restored, were not interrupted as a result of the failure, and the situations posed little risk to patients.

- **5.1.1.2 High impact on all three dimensions**

  At the other extreme, 22 incidents (11%) scored high on all three dimensions of impact. These failures often involved an important patient care task, such as transfusing blood; resulted in substantial delays in patient care; and consumed a substantial portion of the nurse’s workday. These failures were the most complicated to resolve, requiring an average of 5.3 additional tasks, 11.6 minutes of nurses’ time, and the assistance of two other people. They also had a negative impact on efficiency of patient care. High impact failures, on average, took 34 minutes to resolve, with the delayed tasks being time-sensitive items such as meal trays, lab tests, and medications. On average, they resulted in some waste of hospital resources (mean 0.5), such as discarded medications or unnecessary patient preparations. Finally, these failures also interacted with the environment. On average, the task was not completed for another 42 minutes after the failure was resolved and nurses were interrupted 1.7 times. It was conceivable that these failures, in conjunction with other factors, could have harmed patients (mean risk 1.8). These failures cost approximately $414, on average, ranging from $16 to $1,708.

  To illustrate high impact failures, we briefly describe an incident with the highest rating for total impact. It involved an elderly patient scheduled for a colonoscopy that was ultimately cancelled. In preparation for the exploratory procedure, the patient was placed in the intensive care unit; had a naso-gastric tube inserted through a nostril into
stomach through which she received “go-lightly”, a compound used to void her digestive system; and could not take anything by mouth, including food, water, or medications.

After the patient had been receiving the go-lightly for more than three hours, the specialist who was to perform the colonoscopy informed the nurse that the procedure—originally ordered by the patient’s primary physician—was cancelled. The specialist felt that the elderly woman was too frail to withstand surgery to remove any abnormal growths the colonoscopy might find, so there was no point in having her undergo the painful exploratory procedure. We want to be clear: the error was not that the specialist canceled the procedure—a seemingly sage decision—but rather that this decision was made late in the process, after expensive and uncomfortable preparations had begun. In sum, an intensive care unit nurse spent 51 minutes needlessly preparing a patient and dealing with complications brought about by these preparations while the patient was in discomfort and had her regular medications suspended. The approximate cost of this failure was $981.

5.1.2 Cumulative impact of failures

While at times trivial individually, operational failures cumulatively had a more significant impact on nurses and patients. These incidents eroded a moderate portion of the workday. For example, the ten nurses observed for an entire shift spent an average of 9% of their time resolving failures, just slightly less than the 42 minutes overtime worked, on average. Thus, nursing time spent on failures represented a real productivity loss. Furthermore, nursing tasks required on average only two minutes 43 seconds, so even small time chunks wasted on failures could have been used for patient care.
Observations also suggest that failures were repetitive. We saw similar failures both within the same unit at hospitals and across different hospitals. The recurrence of identical problems over time increases the severity of these incidents. For example, nurses only spent one or two minutes looking for equipment such as thermometers, pulse oximeters, or narcotic keys, but each nurse did this six or seven times per shift. Similarly, broad types of failures occurred repeatedly, such as missing medications, insufficient linens or supplies, incomplete change-of-shift reports, and nurses not knowing how to order a particular item. However, there were many different specific situations of these generic failures. For example, we observed missing medications problems as a result of a new order not being relayed to the pharmacy, a transfer patient’s medications remaining behind in the prior unit, transcription errors, and filling errors. Similarly, we saw nurses confused about how to order a particular item, such as paper tape, thermometer probe covers, or an unusual test from the laboratory. Thus, while there were common types of problems, there were myriad different situations.

5.2 Types of work system failures encountered

We now discuss types of failures nurses encountered by categorized them into two types: problems and errors; and three sources: the nurse’s own activities, that of the nursing unit, or breakdowns outside of the department. Of the two types of failures, problems were most prevalent, accounting for 86% of the failures. The median cost of problems was $100 and averaged 50 on the total index of failure severity (0 being least and 100 most severe). We were less able to spot errors--they accounted for only 14% of failures--but they had greater impact. The median cost of errors was $119 and the mean severity index rating was 55. A one-way ANOVA comparing problems and system
errors was significant for cost of failures (F=5.827, p-value = 0.017, df =193), with errors costing more than problems, but was not significant for severity index (F=1.05, p-value = 0.307, df=193).

More than half (61%) of the work system failures resulted from activities outside of nurses’ own units. Failures outside the nursing unit also had greater impact—the median cost and severity of failures stemming from other departments was $127 and 58 compared to $101 and 42 for breakdowns caused by the nurse and $12 and 37 for failures originating in their own nursing units. A one-way ANOVA among the three sources of failures was marginally significant for cost of failures (F=2.55, p-value = 0.081, df=193), and was significant for severity index (F=11.637, p-value < 0.000, df = 193), with failures from outside nursing having more drastic consequences.

Considering the two dimensions simultaneously shows that the most significant failures originated in other departments. First, problems in the supply of information and materials from other departments were noteworthy because they were the most frequent category, accounting for 55% of all failures. The median cost for these incidents was $124. Cumulatively these problems accounted for 56% ($23,863) of total estimated failure costs ($42,685) in our data set of 194 failures. The median score on the overall impact index 56. There were not as many errors stemming from outside nursing—only 3% of failures were of this type—but they had the largest impact on patients, nurses, and the hospital, with a median approximate cost of $662 and a mean impact of 72. Cumulatively, errors originating outside of the nursing unit accounted for 17% of total estimated cost of failures observed.
The large percentage of failures due to faulty supply systems suggests that most stem from other groups’ work routines rather than from conditions directly under nurses’ control. Furthermore, the impact of failures from other departments was greater. This conclusion was supported by five of the thirteen nurses interviewed, who acknowledged that while nurses needed to take responsibility for trying to improve their work environment, many of the day-to-day failures crossed organizational boundaries. Lois, an oncology nurse at Hospital 7, stated that most of the problems they encountered were beyond her nursing unit’s control.

The daily problems we face are from outside of our own unit—central supply and housekeeping, for example. It is not the people on our unit. It is not what we do or don’t order for our supplies. It is a system problem.

Conversely, problems and errors due to situations under nurses’ own control or under the jurisdiction of their unit manager were less significant in both frequency and overall impact. Problems and errors stemming from nurses’ own activities, such as not knowing how to use a piece of equipment, accounted for just 12% of failures, with self-caused errors being more significant (median cost $117) than problems ($10). Finally, failures from nursing units accounted for 27% of the failures, but the median cost was only $12 and the average impact rating only 37. For descriptive statistics and examples of failure types see Table 3.

5.3 Nurse and manager perception of work system failures

For almost half of the failures (84 failures or 44%), nurses responded as if the situations were expected parts of their work routines. Not surprisingly, these failures tended to be less costly and severe. For example, nurses remained undisturbed by 54% of
the problems due to nursing unit activities—which had a median approximate cost of $3 and impact of 29. As nursing unit-caused problems became more severe (44) and costly ($38), nurses responded with concern. This pattern of response is logical; as situations become more costly and have greater implications for patients, nurses are more likely to perceive them as “failures” rather than as acceptable by-products of working in a complex organization. However, what is noteworthy is nurses’ and managers’ acceptance of errors external to nursing, even when these situations have substantial costs and severity. Nurses responded to 67% of these situations, which had an average approximate cost of $515 and an average severity index of 81, without any indication that with some system improvements and redesign, they could be avoided. Managers were not involved in any of the 28 system errors.

We ran an analysis of variance to test whether there was a relationship between estimated cost of failures and perception of the problem as a failure. The differences among the three groups of failures (perceived by all as a failure, perceived only by nurses, perceived by no one as a failure) were insignificant (F=1.52, p value=0.22, total degrees of freedom =193). However, the ANOVA using the impact of the failure was significant (F=14.787, p value <.000, df =193). While a lack of significance is not a finding, it does suggest that nurses and managers are overlooking some failures that bear solution and perhaps are acting on some that are less costly. Table 3 provides a brief description of a sample of failures from each cell.

Insert Table 3 about here
6. Discussion and conclusion

This paper makes a contribution to the failure literature by examining operational failures in their context, as they occur. Data show that failures predominantly arise during preparation for delivery, resulting from breakdowns in the supply of materials or information spanning organizational boundaries. We considered three groups of failures: failures neither nurses and managers responded to as improvement opportunities, ones nurses recognized but managers did not, and ones that both managers and nurses considered worthy of effort. Managers were actively involved in only eight situations (4%), and workers expressed motivation to remove underlying causes for slightly more than half of the failures they encountered. We claim that front line failures were common because managers, and to some extent workers themselves, were unaware that these situations could be actionable improvement opportunities.

It appeared difficult for workers to consider failures as systematic breakdowns that could be prevented and when they did, to raise awareness about the flaw. The challenge we experienced in reliably coding what was and was not an operational failure was representative of a similar problematic issue faced by nurses: when should they notify someone about a failure and when should they struggle through an incident on their own? We assert that the ambiguous nature of operational failures results in workers addressing them on their own and, over time, failures become an expected part of the work routine. Data from interviews and observations suggest that time pressure faced by nurses, their sense of individual responsibility to patients, and the commonly held belief that competent nurses can overcome challenges posed by poorly coordinated hospital systems, make it difficult—and risky—for nurses to voice concern about failures (Tucker
et al, 2002). Furthermore, although failures frustrated nurses, they seemed resigned that daily obstacles were an inevitable part of providing individualized health services. In addition, most failures came from departments that supplied nurses and therefore were not under their direct control. Thus, low expectations and a lack of control over underlying sources of failures contributed to acceptance of failures, a finding supported by recent studies of medical errors (Chassin and Becher, 2002).

It was even more difficult for managers to assess full costs of failures because they were rarely present when failures occurred, did not receive much information from nurses about these situations, and did not experience the impact firsthand. Unfortunately, research suggests that managers’ perceptions about failures can also be inaccurate. Our data showed little correlation between failures that managers attempted to address and estimated costs. Therefore, some failures that are worthy of attention are likely to be ignored while other more trivial situations may receive attention. Our findings suggest an explanation for common lament of healthcare workers that their calls for management assistance in rectifying known trouble spots fall on deaf ears until a crisis emerges (Chassin and Becher, 2002). In sum, higher level support was often insufficient, perhaps because managers were unaware of the failures. Nonetheless, the lack of managerial support was a serious setback as most failures originated in non-nursing units and therefore needed more clout than rank-and-file workers possessed to get other departments to examine and modify their work practices.

Despite difficulty in drawing attention to failures, failures are worthy of solution efforts. Over time, failures can be expensive. We estimate that a 204-bed hospital with 75% occupancy can lose a minimum of $51,000 (uses the minimum cost of $0.33 per
failure) up to a maximum of $27 million (median cost of $177 per failure) per year to operational failures. (Calculations based on a rate of one failure every 74 minutes, each nurse cares for seven patients, 24 hours a day, 365 days a year.) In addition to our estimate of costs due to lost productivity and waste, failures have also been shown to contribute to worker dissatisfaction and consideration of quitting (Peters et al., 1985). More alarmingly, small failures and discrepancies can combine to harm patients (Chassin and Becher, 2002). For example, problems caused delays for patient care, which compromised patients’ health and created additional work for the nurses. These problems also increased the cognitive difficulty of managing and remembering to complete all aspects of patient care, which in turn increased the potential for error (Reason, 1990) and wasted “cognitive set up” time (Watkins and Clark, 1992). Similarly, system errors wasted valuable hospital resources—such as nursing time and medications—and subjected patients to unnecessary procedures.

6.1 Implications

6.1.1 Implications for researchers

This research provides an important new direction for service failure and organization improvement research. Past research has for the most part, neglected actual experiences of workers with failures, and instead has relied on workers’ perceptions of general categories of failures (Peters and O'Connor, 1980; Tesluk and Mathieu, 1999). However, our data show that workers can rapidly compensate for most failures they encounter, limiting worker’s ability to recognize and justify the need for organizational change. Similarly, consideration of only customers’ points of view regarding service
failures misses difficulties that arise before service delivery, which constitute most of the failures we observed. Including these two types of problems—those that are quickly resolved and those that occur during preparation for service delivery—provides greater opportunity for organizations to learn from problems. Finally, past research focused on developing a typology of failures or determining which responses maintained customer satisfaction rather than on understanding the dynamics of how these failures can be eliminated.

6.1.2 Implications for managers

Our findings also have implications for managers who seek to improve front line performance. First, organizations need a process for identifying operational failures—especially inter-group communication and coordination failures, which constitute the majority encountered. Our research provides a possible explanation for research findings that an emphasis on hospital-wide coordination was associated with better patient outcomes (Young et al., 1997). Perhaps such hospitals are able to avoid failures that plague organizations that pay less attention to coordination issues.

Visibility of failures was further hindered by the gap between front line worker and manager awareness of these incidents. We assert that the full extent of failures remained hidden from individuals not directly involved and therefore managers were likely to underestimate the degree to which failures plagued their employees. Our result offers a possible explanation for Auty and Long’s (1999) finding that managers perceived internal service quality as satisfactory, while front line workers regarded it as unsatisfactory. Given that managers usually determine which failures are worthy of
scarce solution resources such a difference in perception can result in these seemingly small annoyances never being selected for resolution. Thus, we conclude that operational failures impact productivity and customer satisfaction, but are unlikely to receive sufficient attention.

Organizations also need procedures for resolving boundary-spanning failures. Solution efforts are likely to involve mechanisms used to request and provide information, goods, and services among different groups (Spear and Bowen, 1999). In addition, research suggests that without manager and organizational support, nurses—given their relatively low organizational power (Chambliss, 1996)—will find it difficult to get other groups to respond to their cross-boundary problem solving efforts (Auty and Long, 1999; Huq and Martin, 2000). For example, doctors are essential to improvement efforts, but are not under direct control of hospital administration and consequently, do not always view themselves as being “suppliers” in need of a change, limiting their participation (Arndt and Bigelow, 1995). Furthermore, nurses who raise awareness of others’ shortcomings run the risk of being perceived as a troublemaker or complainer (Edmondson, 1999).

Managers can also provide problems solving assistance for front line workers. During interviews both managers and nurses expressed their belief that given the high degree of uncertainty and task interdependence in providing health care, work system failures were unavoidable. However, we observed nursing work to be designed as if failures never occur. For example, nurses had little slack time to deal with service failures, managers were often unavailable to assist nurses, and the systems in place to resolve cross-boundary failures—if there were any such systems—were often
cumbersome and ineffective to use. The benefits of focusing on work systems, rather than on individual performance, is well accepted in both medical error and quality improvement literatures (Kohn et al., 2000; Leape et al., 1995; Shortell et al., 1995). However, health care workers behaved as individuals who were responsible for providing good care despite poor work systems rather than individuals who were responsible for creating work systems that ensured good care. We propose that commonly cited recommendations for improving patient care, like training and incentives (e.g., Huq and Martin, 2000), focus on the individual activity level and therefore will fail to resolve work system failures unless they focus on skills needed for identifying and resolving cross-boundary problems.

Examination of specific failures suggests action managers can take to reduce occurrence of common failures. First, reduce task interdependence as much as possible. One way to do this is to have standardized treatments so it is easier for internal customers to request services from internal suppliers (Spear and Bowen, 1999). For example, care paths, an important innovation in healthcare, enables doctors to prescribe a predetermined, standardized course of treatments for patients with common conditions. This comprehensive, easily enacted set of orders eliminates the need to contact doctors for routine medications such as Tylenol. Interdependence also arises when workers share tools and equipment. When possible, workers should have their own set of equipment. For example, nurses on one unit, after noticing how much time they spent searching for the one set of keys to the locked narcotic medicine cabinet, decided to make a set for each nurse. This entailed additional steps to regulate key usage, but they felt the time saved was worth the extra administrative requirements. If equipment is shared—as was
common with expensive diagnostic equipment only used on a subset of patients, such as pulse oximeters and glucometers—each type should have one designated storage location so people know where to look for it. Further, a system that identifies where the item is (or who is using it) when it is in use will save searching for who has the item. Interdependence also arises because workers receive supplies from other departments. Having designated internal suppliers streamlines the process of asking for service and troubleshooting when there is a problem (Spear, 2002). Similarly, managers need to ensure that ancillary functions are adequately trained, motivated, and staffed to perform their responsibilities effectively. Often support roles, such as transport personnel, kitchen workers, housekeeping, and technician, receive low wages, little training, are understaffed, and suffer from high turnover. When ancillary support fails, front line workers are forced to compensate for their shortcomings.

Second, as a result of the extreme time pressure faced by nurses and the small average task time, one and two minute-blocks of time are valuable. Therefore, techniques to streamline tasks and prevent double work due to problems and errors are worthwhile. Workers and managers can together eliminate redundant or unnecessary steps. Every additional step, no matter how trivial it seems, adds to the complexity of completing a task and increases the likelihood of interruption. In addition, managers should strive to minimize potential for failure by designing error-proof checks into delivery of supplies. Similarly, there should be some sort of signal to notify nurses when missing medicines are delivered to a unit and labs are posted on a computer system. This would eliminate unnecessary trips to the medication area or the computer to check if the missing item has been delivered.
Third, we observed recurrence of similar problems, suggesting that individual failures can be leveraged by considering broader issues. For example, when a nurse does not know the order number for requesting more temperature probes, it can be resolved by creating an order book that also includes numbers for ordering other commonly used materials.

6.2 Limitations and future research

Our methodology had several limitations. Collecting data through observation presented several difficulties. The fact that the author was not a medical care provider hindered her ability to understand some events witnessed. Further, observation is subjective; observers’ beliefs influence what is recorded and therefore data may not accurately reflect dynamics of the situation (Miles and Huberman, 1994). Direct observation has also been shown to alter behavior, particularly motivating subjects to perform at higher levels than they would if unobserved (Burke et al., 2000).

A second limitation was what we observed. We did not explore upstream (supplier) and downstream (customer) components of patient care, but instead focused only on nurses. In addition, we primarily observed experienced nurses and not novice nurses or licensed practical nurses who might face a different set of failures than veteran registered nurses. Thus, our understanding of work system failures is incomplete.

Finally, including performance measures, such as nurse turnover and patient satisfaction, would have strengthened the study. We requested nurse turnover and overtime hours from hospitals, but were unable to get comparable figures from all nursing units. The data we were able to collect was limited by variability in hospital
units and our lack of control data, such as the number of competing healthcare organizations. While we recognize these limitations, we assert that benefits gained from having extensive, context-based data outweigh these concerns. Insights from this exploratory study can benefit future research by beginning to develop theory and propositions that can be tested using rationalist research methods such as modeling, experiments, and survey analysis (Meredith, 1998).

Future research studies might track a single type of failure, such as food service mistakes, through the system to find the source rather than focusing on failures solely from a nursing perspective. Future studies should examine comparable units and have a performance measure that is linked to service preparation failures, such as the percentage of lab procedures delayed because of faulty preparations or the percentage of medications supplied incorrectly to hospital units. Ideally, research would be longitudinal in nature to measure the effectiveness of various improvement processes.

6.3 Conclusions

We found that, cumulatively, failures had significant financial implications for hospitals and interfered with patient care but individually often appeared trivial. In addition, characteristics of nurses’ work environment: time pressure, task uncertainty, and task interdependence created conditions under which these irritating—but not debilitating—operational failures were likely to remain unaddressed. Thus, both the nature of operational failures and the work environment contribute to a cycle of inactivity resulting in the persistence of underlying sources of failures, constraining productivity, profitability, and both customer and worker satisfaction. Managers can overcome this
performance hurdle by deliberately taking steps to identify and resolve failures as they arise.

This research has implications for other front line workers who also face an unpredictable, highly interdependent, and demanding environment. Other service workers such as airline crews, air traffic controllers, hotel employees, teachers, and restaurant personnel face similar time-pressured environments where they have multiple customers simultaneously and receive information and material from several functional groups. The tendency to underestimate difficulties that arise from stock outs and failures also exists. Managers frequently focus on more strategic items, such as a new computer system or a facility upgrade. However, failures and system design flaws are inevitable; organizations need to develop problem-solving capabilities that enable them to remove underlying causes of system failures. As organizations become better at recognizing improvement opportunities, they can increase productivity and customer satisfaction.
References


Table 1. Details about hospitals in which nurses were observed

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Type of hospital</th>
<th>Number of beds</th>
<th>Nursing units observed</th>
<th>Unionized nurses</th>
<th>Observation time (hours:min)</th>
<th>% of total observation hours</th>
<th># of nurses interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small community</td>
<td>47</td>
<td>Intensive care unit</td>
<td>Non union</td>
<td>82:35</td>
<td>34%</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Specialty, urban, teaching</td>
<td>98</td>
<td>Surgical</td>
<td>Non union</td>
<td>7:45</td>
<td>3%</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Rural community</td>
<td>134</td>
<td>Medical/surgical</td>
<td>Union</td>
<td>27:19</td>
<td>11%</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Community, private not-for-profit</td>
<td>243</td>
<td>Surgical and Matenity</td>
<td>Non union</td>
<td>34:30</td>
<td>14%</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Community, government</td>
<td>292</td>
<td>Oncology &amp; Med/Surg</td>
<td>Union</td>
<td>15:35</td>
<td>7%</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Community, government</td>
<td>250</td>
<td>Cardiac</td>
<td>Union</td>
<td>1:30</td>
<td>1%</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Teaching, urban</td>
<td>198</td>
<td>Oncology</td>
<td>Non union</td>
<td>20:30</td>
<td>9%</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Pediatric, teaching, urban</td>
<td>163</td>
<td>Oncology</td>
<td>Union</td>
<td>9:11</td>
<td>4%</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Teaching, tertiary care</td>
<td>433</td>
<td>Intensive care unit</td>
<td>Non union</td>
<td>40:30</td>
<td>17%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>239:25</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>
### Table 2. Definitions and summary statistics for service failure impact measures (n=194)

<table>
<thead>
<tr>
<th>Measure</th>
<th>Definition</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of additional tasks</td>
<td>Number of tasks performed by the nurse to resolve the failure</td>
<td>2.0</td>
<td>2.3</td>
<td>12</td>
</tr>
<tr>
<td>2. Direct time spent on problem (minutes)</td>
<td>The number of minutes the nurse spent directly on resolving the failure</td>
<td>4.2</td>
<td>5.2</td>
<td>33</td>
</tr>
<tr>
<td>3. Number of people involved in resolving problem</td>
<td>Number of people the nurse contacted to resolve the failure</td>
<td>1.2</td>
<td>1.1</td>
<td>8</td>
</tr>
<tr>
<td>4. Waste – unnecessary procedures and tasks performed</td>
<td>Rating of organizational losses due to wasted materials, procedures, and loss of confidence in the organization.</td>
<td>0.3</td>
<td>0.8</td>
<td>1 = wasted material or medication 2 = patient or worker was aware of failure potentially causing a loss of confidence in quality of care provided in hospital, 3 = patient procedure was delayed by a few hours or a procedure was performed unnecessarily, 4 = failure postponed patient’s procedure until following day.</td>
</tr>
<tr>
<td>5. Weighted delay until system is restored so that task can be completed</td>
<td>Minutes of delay multiplied by the weight of the delayed task</td>
<td>81</td>
<td>209</td>
<td>1440</td>
</tr>
<tr>
<td>Weight for task that was delayed</td>
<td>Time-sensitive nature of task</td>
<td>2.3</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>6. Indirect time</td>
<td>Minutes nurse spent on</td>
<td>0.8</td>
<td>3.9</td>
<td>39</td>
</tr>
<tr>
<td>7. Weighted indirect delay until task completion</td>
<td>Indirect delay multiplied by the weight of task delayed</td>
<td>28</td>
<td>141</td>
<td>1200</td>
</tr>
<tr>
<td>Delay system is restored (minutes)*</td>
<td>Minutes of delay after the failure was restored until the task was actually completed.</td>
<td>7.8</td>
<td>37</td>
<td>300</td>
</tr>
</tbody>
</table>

| Weight of task delayed | Same as weights for direct delay |

| 8. Weighted interruptions | Number of interruptions multiplied by the severity rating of the task that was interrupted | 1.3 | 2.1 | 12 |
| Number of interruptions* | Number of times the nurse was interrupted as a consequence of failure or resolution efforts. | 0.5 | 0.9 | 6 |
| Weight of interrupted task | Subjective rating of severity of interrupting that type of task. | 1.1 | 1.4 | 1 = interruption is inconsequential such as personal time or when nurse was between tasks; 2 = tasks that posed a low risk to patient safety if the nurse was interrupted, but involved some cognitive set-up time, such as documentation and getting supplies; 3 = tasks that could result in medical errors if nurse was distracted, such as medication preparation; 4 = direct patient care tasks, such as patient bathing, assessment, or medication administration. |

| 9. Risk to patient | A subjective rating of the risk posed to patients by the failure. | 1 | 1 | 0 = no foreseeable risk to patient such as looking for supply ordering forms or general housekeeping; 1 = failure caused discomfort to patient such as delayed food tray when patient was hungry; 2 = potential for risk given other conditions being present, such as confusing orders, missing medications; 3 = failure by itself could potentially cause patient harm, such as last minute medication cancellations or missed orders. |
Table 3. Cost and impact of operational failures analyzed by type, source, and response (N=194).

<table>
<thead>
<tr>
<th>Source</th>
<th>Problem</th>
<th>Error</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who responds as a failure</td>
<td>No. (%)</td>
<td>Median cost (SD)</td>
<td>Median impact (SD)</td>
</tr>
<tr>
<td>Nurse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No one</td>
<td>8</td>
<td>$3 ($16)</td>
<td>32 (18)$^{1a}$</td>
</tr>
<tr>
<td>Nurse only</td>
<td>2</td>
<td>$367 ($191)</td>
<td>59 (35)$^{1b}$</td>
</tr>
<tr>
<td>Nurse &amp; manager</td>
<td>1</td>
<td>$403 ($11)</td>
<td>79$^{1c}$</td>
</tr>
<tr>
<td>Total</td>
<td>11 (6%)</td>
<td>$10 ($190)</td>
<td>41 (25)</td>
</tr>
<tr>
<td>Unit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No one</td>
<td>26</td>
<td>$3 ($294)</td>
<td>29 (28)$^{1a}$</td>
</tr>
<tr>
<td>Nurse only</td>
<td>17</td>
<td>$38 ($182)</td>
<td>44 (25)$^{1b}$</td>
</tr>
<tr>
<td>Nurse &amp; manager</td>
<td>5</td>
<td>$2 ($760)</td>
<td>40 (35)$^{1c}$</td>
</tr>
<tr>
<td>Total</td>
<td>48 (25%)</td>
<td>$11 ($333)</td>
<td>36 (28)</td>
</tr>
<tr>
<td>Outside nursing unit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No one</td>
<td>34</td>
<td>$93 ($50)</td>
<td>37 (26)$^{3a}$</td>
</tr>
<tr>
<td>Nurse only</td>
<td>71</td>
<td>$126 ($33)</td>
<td>65 (22)$^{5b}$</td>
</tr>
<tr>
<td>Nurse &amp; manager</td>
<td>2</td>
<td>$363 ($39)</td>
<td>86 (7)$^{5c}$</td>
</tr>
<tr>
<td>Total</td>
<td>107 (55%)</td>
<td>$124 ($281)</td>
<td>56 (27)</td>
</tr>
<tr>
<td>Total</td>
<td>166 (86%)</td>
<td>$106 ($293)</td>
<td>49 (29)</td>
</tr>
</tbody>
</table>

Individual examples for each type and source of failure.

1a) Nurse lacks knowledge of order number for thermometer probe covers; 1b) Nurse does not know how to operate pain medication pump; 1c) Second baby’s security tag is missing.
2a) Hung right antibiotic, but with wrong name; 2b) Patient not covered by a nurse for two hours because two nurses each thought the other had the patient.
3a) Nurse cannot find the transport monitor; 3b) Pill crusher does not work and patient needs to have pills crushed; 3c) 1st unit of blood hung late, consequently type and cross order expire
4a) Nurse on prior shift entered patient’s diet wrong in computer system; 4b) During change of shift report, outgoing nurse did not mention that patient had been nauseous.
5a) Run out of swabs to take a sample from patient for MRSA; 5b) Necessary medication is late coming up to the floor, delaying radiology procedure; 5c) New type of syringe on pain medicine (Demerol) and nurses do not know how to use it.
6a) Nurse prepare patient for colonoscopy that is cancelled by specialist; 6b) Pharmacy had already entered medication route into computer system, different route than nurse wanted and resulted in duplicate order being entered into computer.
Appendix

Cost estimate
To illustrate how we arrived at our cost estimate, we explain our methods in detail. First, we multiplied the total number of minutes a nurse spent on a problem by $0.33, the 2001 average cost per minute of nursing labor at 100-299 bed hospitals (Anonymous, 2002). Second, to take into account labor costs of people a nurse contacted about a failure, we multiplied the number of additional people by $0.33. This is a conservative estimate because it assumes that other people worked only one minute on the failure and that their wage rate was the same as nurses. It is quite likely that other people spent more than one minute on a failure, but as we do not have accurate data on other people’s time we err on the side of undercounting this expense. Third, to estimate the cost of delayed nursing care, we multiplied the total delay in minutes by $0.694, a rough approximation of the cost per minute of being in a hospital (Easterbrook, 1987). To take into account the time dependence of the task, we divided by four so that only the most time-dependent tasks were assigned the full hospital time cost. Our rationale was that when a patient does not receive the care for which they are in the hospital, their hospital time is underutilized. Fourth, to estimate the cost related to wasted procedures, we again used the average cost of a day in a hospital, $1000, and divided by four so only failures rated highest on hospital loss would be allocated the full cost of a hospital day. Fifth, for patient risk, we multiplied risk ratings by $63, which was calculated by multiplying $1,900—a conservative estimate of average direct costs of an adverse event (Buerhaus and Needleman, 2000) — by 9.2% to take into account that not all risks result in accidents (Leape et al., 1995) and then dividing by three to assign full cost only to
failures with highest risk ratings. Finally, we summed the five components to calculate a total cost for each failure.

**Principal components analysis**

Finally, to succinctly summarize relationships among the nine measures of impact (Tabachnick and Fidell, 2001), we analyzed the data set using exploratory principal components analysis (PCA). PCA is a statistical technique that can be used to determine if a subset of the variables are correlated and collectively account for a large enough percentage of the total variance to be considered as a distinguishable dimension, or construct. These distinguishable constructs are called components. The correlation between each variable and a particular component is the “loading” of the variable on the component. The larger the loading, the stronger the weight the variable has in interpreting the meaning of the component. In this analysis, components with eigenvalues greater than 1.0 and variables with loadings of 0.45 or greater were considered large enough to be retained for further analysis (Tabachnick and Fidell, 2001).

Three components were extracted, cumulatively explaining 57% of the total variance in the impact variables. Retained components were subjected to orthogonal VARIMAX rotation to maximize the magnitude and uniqueness of variable loadings. Each variable loaded on one and only one factor, resulting in a simple, interpretable structure.

The first component, which we termed *complexity* of resolving the failure, explained 25.6% of the total variation in the data set. Three variables loaded on this component: (1) the number of additional tasks performed to resolve the issue, (2) the direct time in minutes that spent on resolving the failure, and (3) the number of people involved in the resolution effort.
The second factor, impact on patient care efficiency, explained 17.6% of the variance. The three variables that loaded on the second component were: (4) a subjective rating of the losses to the organization due to decreased credibility with patients and employees, unnecessary procedures being performed, or materials being wasted; (5) the delay in minutes of being able to complete the patient care task weighted by the time-sensitivity of the task; and (6) the additional time in minutes nurses spent on issues peripheral to resolving the failure (such as documenting the failure or complaining to other nurses).

Finally, the third factor, interaction with environment, explained 13.8% of the variance. This factor addressed the extent to which other aspects of the work environment—such as the nurses’ other responsibilities and patients’ health conditions—interacted with the failure to impact patient care. The three variables that loaded on it were: (7) the delay in completing the task after the system was restored, (8) the number of times the nurse was interrupted as a result of the failure weighted by the importance of the task that was interrupted, and (9) a subjective rating of the potential risk to patient health. Factor loadings are shown in Table.

Insert Table about here

We created three indices, one for each component. To better understand the range of impact, we analyzed two subsets of failures; ones that had either low or high impact on all three components. To do this we created two scatter plots of scores on the three components: interaction with environment versus patient care efficiency and complexity.
of resolution versus patient care efficiency. We looked for patterns in the data to assess breakpoints for high and low scores. For example, there was a cluster of failures that scored below 20 on the index of patient care efficiency and another cluster that scored below 20 on the interaction scale. These low scorers were coded as “0” on their respective components. We looked for similar breakpoints for high scoring failures and coded these as “2”. Failures that were neither high or low were given a coded as “1”. We then summed the codes. Failures with little impact had a sum of zero while the high impact sum was six.
Table. Factor loadings for measure of service failure impact (n=194)

<table>
<thead>
<tr>
<th>Variable</th>
<th>1. Failure complexity</th>
<th>2. Efficiency</th>
<th>3. Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of additional tasks</td>
<td>0.916</td>
<td>0.054</td>
<td>0.086</td>
</tr>
<tr>
<td>2. Direct time spent on problem (minutes)</td>
<td>0.830</td>
<td>0.102</td>
<td>-0.079</td>
</tr>
<tr>
<td>3. Number of people involved in resolving problem</td>
<td>0.726</td>
<td>0.261</td>
<td>-0.049</td>
</tr>
<tr>
<td>4. Waste – unnecessary procedures and tasks performed</td>
<td>0.040</td>
<td>0.781</td>
<td>0.045</td>
</tr>
<tr>
<td>5. Weighted delay until system is restored so that task can be completed</td>
<td>0.103</td>
<td>0.577</td>
<td>0.109</td>
</tr>
<tr>
<td>6. Indirect time (minutes)</td>
<td>0.160</td>
<td>0.545</td>
<td>-0.038</td>
</tr>
<tr>
<td>7. Weighted indirect delay until task completion</td>
<td>-0.051</td>
<td>0.034</td>
<td>0.712</td>
</tr>
<tr>
<td>8. Weighted interruptions</td>
<td>0.439</td>
<td>-0.345</td>
<td>0.604</td>
</tr>
<tr>
<td>9. Risk to patient</td>
<td>-0.125</td>
<td>0.374</td>
<td>0.585</td>
</tr>
<tr>
<td>% of variance explained</td>
<td>25.6%</td>
<td>17.6%</td>
<td>13.8%</td>
</tr>
</tbody>
</table>