# Reducing workload and increasing patient safety through work and workspace design

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# Reducing workload and increasing patient safety through work and workspace design

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ABSTRACT

This report was commissioned by the IOM in order to provide input for a project on work environment for nurses and patient safety. Our report focuses on work design and patient safety for nurses. Work (and workspace) design relies on a large body of knowledge, including ergonomics, job stress and job/organizational design. In this report, we first propose a general framework of work design and patient safety. The proposed framework assumes that when designing or redesigning work one needs to examine different elements of a work system, i.e. the individual, the tasks, tools and technologies, the physical environment and organizational conditions. The second part of the report discusses the work design process, i.e. does what it consist of, the 'toolbox' of tools and methods used to evaluate the work system and design and implement solutions, and principles for successful work (re)design projects. Then, five case studies are described, including three from healthcare and two outside of healthcare. These case studies address issues of hospital facility design (St Joseph's hospital), organizational structure (Magnet hospitals), teamwork in an emergency department, cellular manufacturing, and participatory ergonomics. Finally, a number of recommendations are proposed.

Both specific and general recommendations for successful work (re)design projects are proposed. First, a set of principles for successful work redesign projects is proposed. Second, the role of technology in work (re)design is discussed. It is important to recognize that technology is not always the solution that some believe. Technology is only one element of the work system. Therefore, when designing a technology or when implementing a technology, it is important to understand the other elements of the work system. Third, we discuss the issue of the expertise required to (re)design work. We highlight the simplicity, as well as the complexity of the work design field. Therefore, we suggest a multi-faceted approach to dealing with the expertise issue. Fourth, we strongly encourage every healthcare institution to 'get started'. When it comes to work design and patient safety for nurses, there is a lot that needs to be accomplished and waiting for the ultimate knowledge, method, research study,… that will transform and improve the work of nurses and dramatically improve patient safety is not reasonable. Finally, participation of nurses in all aspects and stages of work (re)design is critical. They are the users, beneficiaries, consumers of work design, and should have input in the work (re)design process.

Participation of nurses will likely improve the outcome of the work (re)design and facilitate its successful implementation.

The report concludes by strongly encouraging healthcare decision-makers at all levels to ‘get started’ in the work design journey. One way of initiating the journey is to start asking questions regarding the various elements of work system:
(1) What are the characteristics of the individual performing the work?
(2) What tasks are being performed and what are characteristics of the tasks that may contribute to unsafe patient care?
(3) What in the physical environment can be sources of error or promotes safety?
(4) What tools and technologies are being used to perform the tasks and do they increase or decrease the likelihood of untoward events?
(5) What in the organization prevents or allows exposure to hazard? What in the organization promotes or hinders patient safety?

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# 1. Introduction

The two recent IOM reports on quality of care and patient safety emphasized the application of engineering concepts and methods, in particular human factors and system engineering, to the design of work systems (Institute of Medicine Committee on Quality of Health Care in America, 2001; Kohn, Corrigan, & Donaldson, 1999). Various engineering principles were described in those reports that have been successfully used in other industries to reduce and/or prevent errors and accidents, such as appropriate application of standardization and simplification of processes, avoiding reliance on memory and vigilance, optimal resource allocation, and the use of constraints and forcing functions. These principles are only some of the many principles that have been developed by engineers to design safe work and work processes. This report will provide a conceptual framework for the 'activity' of work design, and then lay out the methodologies and methods one can use to design or redesign work in order to increase patient safety. The focus of this report is on nursing work. However, many of the concepts and methods can be equally applied to other healthcare professions.

Work (re)design is particularly relevant for nurses and patient safety. First, redesigning work can lead to more efficient and effective use of currently employed nurses. Second, redesigning work provides many opportunities to reduce opportunities for error. Third, redesigning work can also lead to improved worker safety. Nurses are at high risk of many occupational health problems and injuries (Colligan, Frockt, & Tasto, 1979; Punnett, 1987; Stubbs, Buckle, Hudson, Rivers, & Worringham, 1983). Improving worker well-being and safety may be related to improved patient safety (Lundstrom, Pugliese, Bartley, Cox, & Guither, 2002; Sainfort, Karsh, Booske, & Smith, 2001). On the other hand, some job/organizational restructuring and redesign can lead to decreased nurse well-being and satisfaction and can negatively affect patient care (Aiken, Clarke, & Sloanne, 2000). In this report, however, we focus on strategies of work (re)design directly aimed at improving patient safety.

There is much debate around the issue of nursing shortage (Brewer & Kovner, 2001; Kovner, Jones, & Gergen, 2000). Nursing shortage and inadequate staffing have been identified as possible factors contributing to poor unsafe patient care (Beckmann, Baldwin, Durie, Morrison, & Shaw, 1998; Jackson, Chiarello, Gaynes, & Gerberding, 2002; Kovner, Jones, Zhan, Gergen, & Basu, 2002; Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2002), and simultaneously high job stress and low job satisfaction (Aiken, Clarke, Sloane, Sochalski, & Silber, 2002). Some argue that there is an insufficient number of nurses either entering the nursing profession or staying in the nursing profession. Others argue that currently employed nurses are not efficiently and effectively used. This report will not address the issue of nursing shortage directly. However, some of the topics addressed in this report relate to the debate on nursing shortage. First, one reason for the recruitment and retention problem may be the poor working conditions and perceptions of inadequate resources and environment for providing good safe care (Aiken et al., 2001). Work redesign is a process aimed at improving work and work processes, which may lead to increased satisfaction and motivation, and reduced intention to turnover. Work redesign is a primary job/organizational design strategy for dealing with recruitment and turnover (Cotton & Tuttle, 1986; Parasuraman, 1982; Porter & Steers, 1973). Second, work redesign often leads to improved work efficiency and effectiveness. When an organization engages in a work redesign project and improves the overall efficiency and effectiveness of its processes, employees may develop more positive attitudes toward the organization, i.e. increased job satisfaction and commitment to the organization. These positive attitudes have been related to low turnover and increased company 'attractiveness' (Mowday, Steers, & Porter, 1979; Murrell & Sprinkle, 1993).

In this report, we examine the following issues:

- General framework of work design and patient safety
- Work design process: its elements, methods and principles
- Examples inside and outside of healthcare
- Recommendations to healthcare decision-makers

## 2. General framework of work design and patient safety

Work design is based on a very large body of knowledge. We first briefly review the literature on human error and patient safety, and conclude that other approaches are necessary in order to design or redesign work for improving patient safety. We then propose a model of the work system, and describe various pathways or mechanisms between work (re)design and patient safety.

### 2.1 Human error and patient safety

Recently, much emphasis has been put on human factors approaches to patient safety (Bogner, 1994; Cook, Woods, & Miller, 1998; Leape, 1994; Wears & Perry, 2002). The healthcare field has embraced the various models and approaches to human error in order to analyze and evaluate risk and safety (Reason, 2000; Vincent, Taylor-Adams, & Stanhope, 1998). In this section, we discuss the various types of human error, models that describe the chain of events leading to human error, different levels of factors contributing to human error, and categories of factors that influence patient safety.

In the human factors and work sciences literature, models and approaches of human error have been developed to understand the human mechanisms leading to accidents. One of the most prevalent human error models was defined by Rasmussen (1983) and Reason (1990). This model defines two types of human error: (1) slips and lapses, and (2) mistakes. In turn, mistakes can be categorized as resulting from either rule-based behavior or knowledge-based behavior. This taxonomy of human error has been successfully applied to analyze and evaluate accidents in a range of domains, including the nuclear industry (Moray, 1997; Rasmussen, 1982), aviation (Helmreich & Merritt, 1998) and more recently healthcare (Reason, 2000; Sexton, Thomas, & Helmreich, 2000). High-reliability organizations (HROs) pay considerable attention to lapses in performance, especially small lapses, because of the concern that indifference to minor infractions may result in a sense of complacency and a lessened sense of awareness of the consequences of major infractions (Gaba, 2000; Weick & Sutcliffe, 2001). These organizations set rules that must be followed regardless of how relatively inconsequential an infraction may appear.

Another important distinction brought up by the human error literature is that of active and latent errors (Reason, 1990). Active errors have effects that are felt or seen immediately and are associated with the performance of the ‘front-line operators’, such as nurses. Latent errors are more likely to be related to organizational and management factors that are removed in both time and space from the front-line operations. The distinction between active and latent failures, or between the ‘sharp end’ and the ‘blunt end’ (Cook & Woods, 1994), has led to the recognition of the importance of organizational, management and procedural factors in errors and accidents. This had led to the development of a number of models describing the ‘chain of events’ that can lead to an accident or an adverse outcome. For instance, Vincent and colleagues (1998) proposed an organizational accident model that identifies the following chain of events: latent failures (i.e. management decision, organizational processes) influence conditions of work (i.e. workload, supervision, communication, equipment, knowledge/ability), which in turn can lead to unsafe acts or active failures (i.e. omissions, action slips/failures, cognitive failures, violations) that can lead to accidents or adverse outcomes if the barriers or defense mechanisms are insufficient.

There is increasing recognition in the human error literature of the different levels of factors that can contribute to human error and accidents (Rasmussen, 2000). If the various factors are aligned 'appropriately' like 'slices of Swiss cheese', accidents can occur (Reason, 1990). Table 1 summarizes the different approaches to the levels of factors contributing to human error. It is interesting to make a parallel between the different levels of factors contributing to human error and the levels identified to deal with quality and safety of care (Berwick, 2002; Institute of Medicine Committee on Quality of Health Care in America, 2001). The 2001 IOM report on *Crossing the Quality Chasm* defines four levels at which interventions are needed in order to improve the quality and safety of care in the United States: Level A-experience of patients and communities, Level B-microsystems of care, i.e. the small units of work that actually give the care that the patient experiences, Level C-health care organizations, and Level D-health care environment. These levels are similar to the hierarchy of levels of factors contributing to human error (see Table 1). In this report, we focus on work design, i.e. on issues at the three lowest levels. In a later part of the report, we provide recommendations to healthcare decision-makers that may actually have an impact on the highest level, i.e. the health care environment.

The human error literature has produced a number of lists of factors that can influence clinical practice and affect patient safety. For instance, Vincent et al. (1998) categorize those factors into (1) factors that influence clinical practice (i.e. institutional context, organizational and management factors, work environment, team factors, individual-staff factors, task factors and patient characteristics), and (2) team factors and their components (i.e. verbal communication, written communication, supervision and seeking help, and structure of team).

Human error models and approaches provide much information on how to understand, analyze and evaluate near misses and accidents (Shojania, Wald, & Gross, 2002). However, there is another large body of literature in human factors and work sciences that has been relatively ignored in the discussion on patient safety. This body of literature provides much information on how to improve work (Salvendy, 1997). When taking on the project of (re)designing work for improving patient safety, it is important to consider this other large body of literature on human factors and systems engineering.

## 2.2 Work system

The work design body of knowledge can be categorized into (1) ergonomics (or human factors), (2) job stress, and (3) job/organizational design. According to the human error literature, a variety of different levels of factors can contribute to accidents. Whereas models describing the 'chain of events' leading to accidents are interesting and useful for analyzing and evaluating specific accidents, other models and approaches need to be considered when redesigning work. Unlike the human error literature, these other models put little emphasis on understanding and dissecting the specific mechanisms that lead to human error and accidents. They provide information on *how* to change work. The concept of 'system' in patient safety and quality of care has been largely emphasized (Berwick, 2002; Donabedian, 1980; Institute of Medicine Committee on Quality of Health Care in America, 2001; Leape, 1997). In this report, the concept of 'system' is used in a very specific sense: a system represents the various elements of work that a nurse uses, encounters and experiences in order to perform his/her job.

*2.2.1 Work system model*

Designing or redesigning work requires a systematic approach that takes into account the many facets or elements of work. The work system model developed by Carayon and Smith is a very useful model of the many different elements of work (Carayon & Smith, 2000; Smith & Carayon-Sainfort, 1989). The work system is comprised of five elements: the <u>individual</u> performing different <u>tasks</u> with various <u>tools and technologies</u> in a <u>physical environment</u> under certain <u>organizational conditions</u> (see Figure 1). See Box 1 for an example of how the work system model can be applied to the analysis of an intensive care unit nurse.

BOX 1 – EXAMPLE OF WORK SYSTEM ANALYSIS OF AN ICU NURSE

The following is a brief overview of the different work elements of an ICU nurse job.

*The task.* The tasks performed by the ICU nurses include (but are not limited to) direct patient care, continuous patient status assessment, carrying out physician orders, medication administration, and family interaction.

*Organizational factors.* There is a range of organizational factors that are important to understand the job of an ICU nurse. Conflict among nurses and between physicians and nurses has been correlated with high stress and workload in ICUs (Gray-Toft & Anderson, 1981). The studies by Knaus, Rousseau, Shortell, Zimmerman, and colleagues have shown the importance of 'caregiver interaction', which is a composite concept that includes several dimensions, such as communication and coordination (Knaus, Draper, Wagner, & Zimmerman, 1986; Shortell et al., 1994).

*The environment.* Noise and other sensory disruptions abound in the modern ICU setting (Topf, 2000). The physical environment is often crowded and messy, with no one available to help with immediate clean up of the environment or equipment. The noise, the housekeeping, the level of constant activity, the size of the rooms or physicians' and nurses' personal space (if any), patients/staff coming and going, crowds of people waiting to get a moment of the physician's or the nurse's time and attention may all make the physical environment more difficult to carry out tasks.

*The equipment and technology.* The technology, tools and equipment of modern ICU have been identified as possible causes of errors and problems (Bracco et al., 2000). The availability of needed supplies, the type of supplies, tools, technology desired, the working condition of the equipment, and the new technology available or unavailable are but some of the tools and technology issues that can increase workload. Additionally, training and time for acclimation is needed to learn all the new tools and technology.

*How to balance the work system of an ICU nurse, in particular with regard to workload?*

As an example in the ICU setting, in efforts to reduce workloads and balance the overall work system, the physicians and nurses might review how often physical assessments are performed on the patients and who performs them. Typically, both the nurse and the physician perform a patient physical assessment every hour, or as needed by patient's condition. Under this system, both the physician and the nurse perform the patient physical assessment and enter it into the patient's records. The process takes the health care provider at the least several minutes or more, depending on the patient's status, out of every hour. This takes time away from other tasks and/or professional activities associated with the patient's care. In addition, others such as specialty consultation services may be waiting to review the patient record currently in use for the patient assessment. To balance this problem, the ICU physicians and nurses may redesign the patient assessment system based on clinical expertise and cooperation among the physicians and the nurses involved.

*2.2.2 Task analysis and job design*

It is important to understand the various levels of work that can be evaluated and redesigned. Task analysis and job design are central features of work (re)design. Task analysis ensures that human performance requirements match workers' needs and capabilities and that the system can be operated in a safe and efficient manner (Czaja, 1997), whereas job design go beyond the tasks and include issues such as work content, distribution of work and work roles, coordination and rewards (Davis & Wacker, 1987). Some of the earliest approaches to task analysis are to be found in the work study approaches developed by Frederick Taylor (1911) and the Gilbreths. They developed techniques to observe, record and codify work activities, i.e. elements of tasks. The overall objective of the work-study approach was 'efficiency'. The goal of Taylor's Scientific Management approach was to determine the 'one best way' to perform a task and to reduce inefficient or wasteful activities.

The diversity of task analysis approaches has dramatically increased over the years (Luczak, 1997). Kirwan & Ainsworth (1992) have compiled a taxonomy of categories which have been used in various studies of task analysis. The taxonomy of task analysis includes: (1) description of task (e.g., type of activity/behavior, task-action verb, function/purpose, sequence of activity), (2) requirements for undertaking task (e.g., initiating cue/event, information, skills/training required, personnel requirements), (3) tools and technologies (e.g., location, job aids), (4) nature of the task (e.g., actions required, decisions required, responses required, complexity, difficulty, criticality), (5) performance on the task (e.g., performance, time taken, required speed, required accuracy), (6) other activities (e.g., subtasks, coordination requirements, concurrent tasks), (7) outputs from the task (e.g., output, feedback), and (8) consequences/problems (e.g., likely/typical errors, errors made/problems, error consequences, adverse conditions/hazards). This taxonomy shows the many different aspects of a task that can be examined. In section 3.10, we discuss one particular work design method that is directly related to task analysis: work sampling. It is important to understand that the work sampling method fits in the general framework of Taylor's Scientific Management: work sampling assumes that data can be recorded on tasks (e.g., duration, frequency, purpose), and very often these data are used to reduce inefficient or wasteful activities. However, there are a number of other objectives and applications of work sampling.

Job design is a more encompassing work design approach as compared to task analysis. It examines work at a higher level. Job design is concerned with all of the elements of the work system, including organizational issues such as coordination, distribution of work and work roles. For instance, Davis and Wacker (1987) highlight 8 issues of importance to job design: (1) meaningful and challenging work, (2) opportunity to learn on the job, (3) some scope of decision-making, (4) social support in the workplace, (5) recognition of one's contribution, (6) relationship between one's work role with one's outside life, (7) desirable job future, and (8) options in one's job to accommodate individual differences and circumstances. This list of job design criteria is only one example of many job design criteria that one can use in redesigning work (see tables 3 and 4 for other theories and models of job stress and job/organizational design that provide additional design criteria). Job design includes considerations of importance to task analysis (e.g., task performance and error), but is also concerned with psychosocial considerations, such as satisfaction and motivation, stress and strain, and overall health and well-being.

### *2.2.3 Improving work*

Describing the work system, its elements and their interactions is only the first step in work design (see Box 2 for a set of questions one may ask when describing the work system). We also need to evaluate the work system and its elements, that is to define the positive and negative aspects of the work system elements. The evaluation of the positive and negative aspects relies on knowledge in the fields of ergonomics, job stress and job/organizational design. These three fields of research have developed a number of theories, models and principles that characterize 'good' work. This information is important for not only evaluating the work system, but also for designing solutions for improving the work system and subsequent outcomes, such as performance and patient safety. Once the positive and negative aspects of the work system and its elements have been defined, we need to come up with solutions that will improve the work design and increase patient safety.

| BOX 2 - QUESTIONS ON THE ELEMENTS OF THE WORK SYSTEM |
|---|
| 1. What are the characteristics of the <u>individual</u> performing the work? Does the individual have the musculoskeletal, sensory, and cognitive abilities to do the required task? If not, can any of these be accommodated for the task?<br>2. What <u>tasks</u> are being performed and what are characteristics of the tasks that may contribute to unsafe patient care? What in the nature of the tasks allows the individual to perform them safely or assume risks in the process?<br>3. What in the <u>physical environment</u> can be sources of error or promotes safety? What in the physical environment insures safe behavior or leaves room for unsafe behavior?<br>4. What <u>tools and technologies</u> are being used to perform the tasks and do they increase or decrease the likelihood of untoward events?<br>5. What in the <u>organization</u> prevents or allows exposure to hazard? What in the organization promotes or hinders patient safety? What allows for assuming safe or unsafe behavior by the individual? |

Solutions for improving work design and patient safety may involve the elimination of negative aspects of the work system. Since eliminating these negative aspects may not be feasible, solutions for improving work design may involve other elements of the work system that compensate for or balance out the negative aspects. This compensatory effect is the essence of the Balance Theory proposed by Carayon and Smith (Carayon & Smith, 2000; Smith & Carayon-Sainfort, 1989). In many situations, it may not be possible to eliminate negative aspects of the work system because of constraints due to the physical design, due to the infrastructure, due to cost, due to recruitment constraints, etc… In those situations, it is important to come up with work design solutions that take into account those negative aspects and try to minimize their impact on workers and patient safety. See Box 1 with the example of the ICU nurse for an illustration of how the work system can be balanced.

Tables 2, 3 and 4 provide a list of theories and models of ergonomics, job stress and job/organizational design. Each of the theories or models provides information on one or several elements of the work system. This information helps in defining the positive and negative aspects of the work system and its elements, as well as identifying possible solutions for redesigning work and improving patient safety. For example, various fields in ergonomics can help in designing appropriate features of the physical work system, such as noise, workspace and workstation. The Job Strain model of Karasek and Theorell (1990) identifies two key job stressors: workload and lack of control. According to this model, it is the combination of high workload and low job control that is the most stressful. When workload cannot be reduced (and this is often the case), this model recommends that workers be given more control over various aspects of their work. These are only examples of criteria for 'good' work. Appendix A has a bibliography of basic references on work design.

Studies among nurses have examined aspects of work, such as job characteristics (Tonges, Rothstein, & Carter, 1998; Woodcox, Isaacs, Underwood, & Chambers, 1994), role stress (Woodcox et al., 1994), patient handling tasks (Owen, Garg, & Jensen, 1992), etc… These studies have examined various aspects of work among nurses, but have not adopted the system approach to work design and patient safety that has been recommended by many experts (Bogner, 1994; Leape, 1997).

The five elements of work (i.e. the individual, tasks, tools and technologies, physical environment, and organizational conditions) represent a system because they influence each other, and they interact with each other. A change in any one element of the work system can have effects on the other elements. This system concept has a number of consequences for work (re)design:

- We cannot look at one element of work in isolation.
- Whenever there is a change in work, we need to consider the effects on the entire work system.
- The activity of work (re)design necessitates knowledge and expertise in a variety of elements, e.g., environmental design such as lighting and noise, job design such as autonomy and work demands, and organizational design such as teamwork.
- Work redesign aims at removing the 'negative' aspects of work, that is the aspects contributing to poor performance and unsafe patient care. When this is not feasible, work redesign involves building or relying on other elements of work to compensate for or balance out the negative aspects of work.

<u>2.3 Pathways/mechanisms between work (re)design and patient safety</u>

The literature on work design has identified many different mechanisms on the relationship between work (re)design and worker satisfaction, motivation and performance (see BOX 3). We have identified four different pathways or mechanisms between work (re)design and patient safety.

BOX 3 - JOB REDESIGN AND PERFORMANCE – POSSIBLE PATHWAYS

How does work (re)design lead to improved performance? In the context of job redesign, Kelly (1992) has identified five possible pathways between job redesign and improved job performance. First, job redesign leads to improved job perceptions and job satisfaction, which in turn many positively influence intrinsic motivation. Workers who are intrinsically motivated are more likely to perform more and better. Second, job redesign may lead to increased extrinsic motivation because of pay rises or improved promotion prospects. Workers who are extrinsically motivated are more likely to perform more and better. Third, performance may improve if workers perceive closer links between effort, performance and valued rewards [expectancy theory]. Fourth, job redesign may be accompanied by goal setting: employees either set themselves new performance targets or management sets new performance targets. There is considerable evidence that goal setting is a powerful motivator, in particular under specific conditions (e.g., difficult goals). Fifth, it is possible that when redesigning a job one discovers structural inefficiencies such as inadequate access to equipment. These inefficiencies may be overcome by work methods improvements that are part of the job redesign.

First, redesigning work may directly target the causes or sources of patient safety problems. Various work design methods, such as FMEA and RCA, may allow the identification of errors and specific work system factors that contribute to patient safety problems. Studies performed in manufacturing have shown relationships between ergonomic deficiencies (e.g., poor working postures) and poor quality of assembly (Axelsson, 2000; Eklund, 1995). Redesigning work may therefore remove the sources of possible error and improve quality of work, i.e. patient safety in the context of nursing work.

Second, work redesign may lead to improved efficiencies. Inefficiencies can be considered as ‘performance obstacles’ (Brown & Mitchell, 1991; Park & Han, 2002; Peters, Chassie, Lindholm, O'Connor, & Kline, 1982), that is aspects of the nurses’ work system that hinder their ability to provide good safe patient care. Removing inefficiencies may directly or indirectly improve patient safety. Inefficiencies may represent sources of error or conditions that enhance the likelihood of error. Sources of performance obstacles or inefficiencies can be categorized according to the work system model: task-related inefficiencies (i.e. lack of job-related information, interruptions), tools and technologies (e.g., poor functioning or inaccurate equipment, inadequate materials and supplies), organizational inefficiencies (e.g., inadequate staffing, lack of support, lack of time), and physical environment (e.g., noisy, crowded environment) (Peters et al., 1982; Peters & O'Connor, 1980). Removing performance obstacles and inefficiencies may free up time and reduce workload, therefore reducing the likelihood of error (more efficient use of currently employed nurses).

Third, work redesign may lead to improved effectiveness. Whereas efficiency is the degree to which work is performed well, effectiveness relates to the content of work itself: are we doing the right things? Work redesign may lead an organization to ask itself questions regarding task allocation (who is doing what?), job content (what tasks should be performed that are not performed and what tasks are performed that should not be performed?), etc… For instance, Hendrickson et al. (1990) conducted a study on how hospital nurses spend their time. Work sampling techniques were used to evaluate time spent in various activity categories (i.e. with patient, patient chart, preparation of therapies, shift change activities, professional interaction, miscellaneous activities, checking physician’s orders, unit-oriented inservice, paperwork, phone communications, supplies, miscellaneous non-clinical). Results show that within a typical 8-hour shift nurses spend an average of 31% of their time with patients. Such results may lead to the re-examination of the tasks and content of the nursing jobs. Work redesign can contribute to increased efficiency, i.e. the elimination of unnecessary activities, and may free up time for the nurses to provide better, safer patient care.

Fourth, Donabedian's framework for assessing quality of care can fit the work system model and provide justification for another pathway between work design and patient safety (Donabedian, 1978, 1980, 1988). In Donabedian's model, the **structure** includes:

- *the organizational structure*: the organization's levels of management and its reporting channels; its compliance with regulations, policies and procedures (work system model element = organization);
- *the material resources*: the facilities, instruments and technology used for providing care (work system model elements = environment, tools/technology);
- *the human resources*: the qualifications and ongoing training and education of staff; the roles of staff as defined in position descriptions and professional guidelines (work system model elements = worker, tasks).

Donabedian's two other means of assessing quality include evaluating the **process(es)** of care – how worker tasks and clinical processes are both organized and performed (e.g., Was the care provided in compliance with the clinical pathway? Was medically indicated care provided?), and evaluating the **outcome(s)** of care – assessing the clinical results and impacts of and patient satisfaction with the care provided. Donabedian (1980) concludes that a direct relationship exists between structure, process and outcome.

Assessing patient safety can be accomplished using the same framework. The structure of an organization affects how safely care is provided (the process); and the means of caring for and managing the patient (the process) affects how safe the patient is upon discharge (outcome). For example, providing intentionally consistent and repetitive patient education by multiple nurses concerning the patient's self-management of her respective medical condition while receiving inpatient care, can positively affect how capable she is of safely caring for herself at home. Likewise, a nurse who follows a regular work schedule and does not work overtime may be less likely to submit a patient to unsafe care. This work practice also enhances the maximum potential of the employee. Finally, introduction of a new technology aimed at decreasing medication errors may fall short of achieving the technology's desired objective if inadequate planning and attention are paid to the task and worker aspects of the work system model prior to and during the implementation of the new technology. Consequently workers may not be able to fully comply with the use of the technology because of work design or satisfaction issues.

We suggest that the work system model applied to patient safety complements Donabedian's framework. Overall, the *work system* in which care is provided affects both the work and clinical *processes* which in turn influence the patient and organizational *outcomes* of care. Changes to any aspect of the work system will, depending on how the change or improvement is implemented, either negatively or positively affect the work and clinical processes and the consequent patient and organizational outcomes. Redesigning a work system requires careful planning and consideration to ensure that neither the quality of care nor patient or worker safety are compromised because of a lack of consideration to all of the elements of the work system. Likewise, subsequent review of the success of change in an organization cannot be fully accomplished without assessing the entire work system, the clinical and work processes and both the clinical and organizational outcomes of patient care.

We have identified four pathways or mechanisms between work (re)design and patient safety:

1. Work redesign may directly target the causes or sources of patient safety problems.
2. Work redesign may lead to improved efficiencies by removing performance obstacles, therefore freeing up time and reducing workload for nurses to provide better, safer patient care.
3. Work redesign may lead to the re-examination of who does what, i.e. the objectives of work, and indirectly improve quality and safety of care.
4. Work design can be considered as part of the ‘Structure’ element of Donabedian’s model of quality of care. Therefore, improving work can improve care processes, and therefore patient outcomes, including patient safety.

## 3. Work design process

Designing or redesigning work can represent a major organizational investment requiring the involvement of numerous people, substantial time to conduct evaluations, analyze data and design and implement solutions, adequate resources and sufficient expertise and knowledge. Like any major organizational or technological change, work (re)design needs to be 'managed'. A process needs to be implemented for coordinating all the personnel, activities and resources involved in the work (re)design project.

The work (re)design process involves the following pieces:

- A series of steps and activities logically and chronologically organized (section 3.1)
- A 'toolbox' of tools and methods that one can use to evaluate the work system and design and implement solutions (sections 3.2 to 3.10)
- A set of overarching principles that can guide an organization when embarking into a work (re)design project (section 3.11).

### 3.1 Work design processes

Many work design processes have been identified and proposed (Wilson, 1995b). They take different forms, have different levels of specifications and use different terminologies. However, they all can fit into a sequence of *analysis*, *synthesis* and *evaluation*. Wilson (1995b) proposes an ergonomics design process with 12 steps. Figure 2 describes the steps of the process. This ergonomics design process is very detailed with regard to analysis, but may lack details and specifications for synthesis and evaluation. The structured work redesign process proposed by Parker and Wall (1998) includes 8 phases and is displayed in Figure 3.

In order to implement the work design process, tools and methods need to be used for each of the different steps. At the analysis stage, the following tools can be used: job analysis, FMEA and root cause analysis, process analysis, interdependence analysis/variance analysis, ergonomic analysis, and work sampling. Some of these same tools can be used to identify solutions for work redesign: process analysis, interdependence analysis/variance analysis, and ergonomic analysis. Other tools can be used to design solutions: allocation methods, and simulation. In the following sections, we describe these methods. As much as possible, we provide examples of how the work design methods have been applied in healthcare for nursing jobs. However, some of these methods may be new to healthcare and have not been widely (or not at all) applied.

### 3.2 Job analysis

A job analyst examines all the different elements of the work system, and records data in a form. An example of a job analysis form developed at the University of Wisconsin-Madison is included in Appendix A. A job analysis form allows the analyst to keep track of all the information gathered on the following elements of the work system: the individual, tasks, tools and technologies, physical environment, and organizational conditions.

Different approaches can be used to collect data on the work system: direct measurement, observations, questionnaire, interviews, review of organizational documents (e.g., position description, organizational chart), and analysis of archival data (e.g., patient satisfaction data, error reporting systems). Each data collection approach has both weaknesses and strengths (Wilson & Corlett, 1995). It is important for the job analyst to use multiple data collection approaches. Each approach has strengths and weaknesses, and the use of multiple approaches provides greater confidence in the data collected. The case study on participatory ergonomics described in section 4.5 shows how a variety of data collection approaches were used to diagnose a work system, to get feedback on the implementation process, and to evaluate the impact of the work redesigns.

3.3 RCA

Root cause analysis is a tool that has long been used in engineering to examine organizational or systems problems (Feldman & Roblin, 2000). All systems have problems that plague their operations, lower efficiency, and create customer dissatisfaction. In the case of heath care systems, customer dissatisfaction can range from not finding convenient parking to serious patient co-morbidity and mortality. Sometimes, healthcare organizations try to fix these problems quickly without determining what caused them in the first place; not surprisingly, often making the same problems reappear again and again in the system. Root cause analysis is the process of finding and eliminating the cause(s), which should prevent the problem from returning (Joint Commission on Accreditation of Healthcare Organizations (JCAHO), 2002). Only when the root cause is identified and eliminated can the problem be solved. There are many problem identification methods; however, the process of root cause analysis develops a logical and repeatable analysis approach that involves the following questions:

- What happened?
- Why did it happen?
- What were the most proximate factors?
- Why did that happen? What systems and processes underlie those proximate factors?

Implementation of root cause analysis may bring benefits to a health care organization (Gosbee, 2002; Rex, Turnbull, Allen, Vande Voorde, & Luther, 2000; Wald & Shojania, 2001):

- Develop a logical approach to problem solving, using data that already exists in most health care organizations
- Identify barriers and the causes of problems, so that permanent solutions can be found
- Identify current and future needs for organizational improvement for both the event under analysis and for adverse events that could occur in the future (see FMEA)
- Establish repeatable, step-by-step processes, in which one process can confirm the results of another
- Generate data relevant to job (re)design both at group and individual levels.

Additionally, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) requires that healthcare organizations respond to all sentinel events in a thorough, timely and credible manner of the occurrence using a root cause analysis. The JCAHO also requires that the organization produce an action plan, based on this root cause analysis, consisting of process and system improvements and an evaluation of the effectiveness of any improvements likely to eliminate the risk of such future occurrences (Joint Commission on Accreditation of Healthcare Organizations (JCAHO), 2002).

Gosbee (2002) describes ways that human factors principles can be used by RCA teams. Shojania et al. (2002) describes how RCA was used in a real case. They categorized the ‘contributory causal factors’ as people, information technology, environment, organization, processes, and equipment. Rex et al. (2000) propose a taxonomy of 6 factors that can contribute to an incident and that should be analyzed in an RCA: environment, equipment, leadership, communication, people, and procedures and performance standards. They used this approach to investigate serious adverse drug events that occurred at a tertiary hospital. There are different approaches for categorizing root causes. RCA may use the elements of the work system model (see Figure 1) as a way of identifying the factors that contribute to a patient safety problem or adverse event.

### 3.4 FMEA

A failure mode and effects analysis (FMEA) is an engineering technique used to define, identify and eliminate known and/or potential failures, problems and errors from the systems, design, process and/or service before they reach the customer (American Society for Quality Control Statistics Division, 1983; Stamatis, 1995). It is a method of identifying and preventing product, service, or process failures before they occur. FMEAs focus on prevention (i.e., "fix it before it breaks"). The objective of an FMEA is to look at all of the ways a device or process can fail, analyze risks, and take specific actions to prevent any future occurrences from happening. Typical applications include preventing material or device defects, improving patient care processes, identifying potential safety issues both to patients and care providers, and increasing patient satisfaction (Stamatis, 1995). FMEAs are typically conducted by multidisciplinary teams within the organization on everything from patient care processes to device design. There are both design FMEAs and process FMEAs. FMEAs are not just for new product selection or new processes; but rather, organizations can benefit from conducting FMEAs on existing products or processes.

The FMEA process includes forms and customized evaluation criteria that provide a standardized, comprehensive approach, greatly reducing the variation of this preventive action process. The process allows the multidisciplinary, cross-functional teams to share and understand information in a common language. Both technical and non-technical people can easily use the FMEA process. The FMEA process involves the following steps (Joint Commission Resources, 2002):

- Step 1 – Select a high-risk process and assemble a team
- Step 2 – Diagram the process
- Step 3 – Brainstorm potential failure modes and determine the effects
- Step 4 – Prioritize failure modes
- Step 5 – Identify root causes of failure modes
- Step 6 – Redesign the process
- Step 7 – Analyze and test the new process
- Step 8 – Implement and monitor the redesigned process.

Implementation of a FMEA can result in numerous benefits (Joint Commission Resources, 2002):

- identify potential failures and warranty problems associated with medical devices both after purchase and in new product selection
- identify cost reductions and quality improvement opportunities throughout the system
- reduce the cost of making changes by identifying issues early in the policy and procedures cycle prior to full implementation

- demonstrate an organization's commitment to a comprehensive quality system
- provide an excellent preventive action tool as required by JCAHO.

An FMEA may take two approaches. First, FMEA uses historical data for similar care processes or medical devices as the ones under study. FDA warnings, JCAHO Sentinel Events, scientific published literature and any other appropriate information could provide an impetus for defining failures not previously encountered in an individual setting. Second, inferential statistics, modeling, simulations and reliability engineering may be used to identify and define failures (Stamatis, 1995). Both approaches are accurate, efficient and correct, if done properly. The current FMEA health care trend is to use the first approach, basing initiation of an analysis on high risk/high volume processes, the scientific literature, FDA, CDC or similar agencies alerts, JCAHO Sentinel Events Alerts reporting and soliciting staff suggestions.

Before implementing a work redesign, FMEA may be an important method which will prevent failures and errors from occurring and reaching the customer/patient (Kececioglu, 1991). This early warning or preventative technique provides a methodical way of studying the cause and effects of failures before the work redesign is finalized; hopefully, providing all the ways in which a failure can occur. For each failure, an estimate is made of its effect on the total work system, of its seriousness, of its frequency and of its ease of detection.

According to Stamatis (1995), an effective FMEA has the following characteristics:

- Identifies known and potential failure modes
- Identifies the causes and effects of each failure mode
- Prioritizes the identified failure modes according to the risk priority number (RPN) – the product of frequency of occurrence, severity and detection or criticality index product of the severity and likelihood ratings
- Provides for problem follow-up and corrective action.

As an example, let us consider the implementation of bar coding pharmaceuticals designed to eliminate medication errors due to miscommunication, misidentification and administration failures. The hospital is using bar codes as a means of identifying medications and patients, and expects to drastically reduce the possibility that a patient might be injured by a medication error. The following case study or scenario is a work system analysis of this bar coding technology for nurses work. The medication order appears on the screens of laptop computers used by nurses as they make their rounds. Using a hand-held scanner, the nurse matches the bar code on the medication with the bar code on the patient's wrist band. Using the wireless computer system incorporated into the health care setting, the laptop checks with a central data source to confirm the right dose is being given to the right patient at the right time. The system also performs other safety checks and electronically updates the patient's records as to what is given, when it is given and by whom it is given and then alerts the nurse when it is time to administer a medication again. Additionally, it alerts the nurse when the medication time has come. It also automatically posts the medication charges to the patient's bill.

An FMEA on the implementation of bar coding technology in nurses work may benefit from considering all elements of the work system (see Figure 1). Here are some questions one may ask during an FMEA on the possible failures of the work system when the bar coding technology is introduced:

*Individual (Nurse)*

- Is the nurse computer literate?
- Is the nurse able to read a laptop display?
- Does the nurse have the physical strength or agility to use the laptop or the bar coding gun bedside?

*Tools/Technology*

- What technology is needed to complete this task?
- Is there poor design in this technology? How usable and user-friendly is the interface design?
- Does the technology increase workload because the nurse fears inadequate skill to learn the technology? Does the nurse fear loss of the job skill because of the new technology?
- Is the technology accessible? Can the display font be adapted for better vision? Does it accommodate keyboard use with large and small hands alike? Does it provide safe operation, designed to eliminate cumulative musculoskeletal injuries?
- What are the energy requirements of this technology? Will it run low on or out of power in the course of use?

*Environment*

- Do sensory disruptions make it difficult to use this technology? Can an alarm be heard over other noise in the patient area?
- Does the technology perform under low or no light conditions?
- Are the laptops and bar code guns and their power sources convenient to use? Or does the unit layout inhibit their procurement, causing delays in use?

*Tasks*

- Is there time to learn to use and become acclimated to this new technology?
- Was there nursing participation and control in the decision to purchase this new technology?
- Will this new technology cause task overload, adding too much to the process of patient medication administration? Or will this new technology cause and task under load, possibly causing elements of patient medication to be overlooked?
- Will task content (medicating patients) become repetitive or lose meaningfulness with this new technology?
- Will the nurse feel this is electronically monitored “paced work”? Since all bar coded medication administration times are recorded in a central database, will this be used for nursing time-use studies and electronic performance monitoring?

*Organization*

- The industry is waiting for the Food and Drug Administration to standardize the way medicines are bar-coded, currently not all medications are available. Does this increase workload on various departments such as pharmacy and central processing to provide in-house bar coding?
- Is there sufficient investment in hardware, software and training?
- How will nursing services cover other patient care activities during technology implementation?

As illustrated in the example above, all parts of the work system must be considered in any work redesign such as implementing bar coding technology. A good FMEA aims at identifying potential critical system failures. This identification may be addressed in a powerful manner by examining all elements of the work system. The example above shows how a series of questions on the elements of the work system can be used to identify failure modes, as well as possible causes and effects of failure.

Root Cause Analysis (RCA) and FMEAs, what is the difference?
Root cause analysis is always done in response to an event occurring. The data used to describe the occurrence are retrospective, and are then reviewed to re-construct what might have happened to "cause" this particular outcome. An FMEA's structure is based on events that have not yet occurred. The FMEA structure shows not only the potential for error, but also how severe the problems may be if something does go wrong. Most importantly, the FMEA goes beyond just stating potential incidents. It reveals how to redesign processes to reduce risk and prevent these incidents from occurring.

Comparison of RCA and FMEA (based on JCAHO RI.1.2.2)

| RCA | FMEA |
|---|---|
| SIMILARITIES | |
| Both non-statistical methods of analysis | |
| Both should reduce the risk of patient harm | |
| Both involve identifying conditions that lead to patient harm | |
| Both are activities involving multi-disciplinary teams | |
| DIFFERENCES | |
| Reactive to event occurring | Proactive analysis prior to event occurring |
| Focuses on the event | Focuses on entire process |
| Hindsight bias | Observer bias |
| Fear of identification in process | Nothing has occurred; therefore, no fear of being identified with cause |
| Asks "why, why why" | Asks "what if, what if, what if" |

3.5 Process analysis
Process analysis is a useful Quality Improvement (QI) method that examines a process and identifies the tasks that lead from a certain set of inputs to an output. In the context of work (re)design, process analysis can be used to analyze specific work processes that include one or several tasks (Luczak, 1997). Process analysis can also be used in conjunction with the simulation game method (see section 3.4). A process analysis can produce a graphical representation of the steps or events that occur during the performance of a task or a series of tasks, i.e. a flowchart or a flow diagram (Mesker & Campion, 1997). See Kachhal (2001) for an example of the application of flowchart to document patient flow in an outpatient clinic. Flowcharting is useful when one needs to describe how a process works or should be working (Provost, 2001). Flow charts can be used to highlight delay and storage elements which are affecting the performance and safety of tasks (Drury, 1995). Flowcharting is also useful to communicate about a process, i.e. to explain how a process should be carried out. There are a number of symbols and varying software available to produce flow charts (Mesker & Campion, 1997; Provost, 2001).

A work process analysis can be performed by using the elements of the work system model. The tasks of the work system model can be considered as the basic elements or steps of the work process. Each task of the work process can be described as being performed by a certain individual with specific tools and technologies in a physical environment (i.e. location). In such a work process analysis, one could also specify a number of organizational conditions. For instance, the work process analysis may identify links between tasks, signaling a need for coordination and collaboration across jobs. This type of work process analysis was used by Rogers (2002) in analyzing various work processes impacted by the introduction of Electronic Medical Record technology in a small family medicine clinic. For instance, the patient care process includes the following tasks or steps: check-in patient, patient preparation, physical exam, set up future appointment, and document visit. Each task is represented by a box that includes information on (1) the task, (2) who performs the task (individual), (3) tools and technologies used for the task, and (4) the location where the task takes place (physical environment). This type of work process analysis is much richer than the traditional process analysis because it provides information not only on the tasks that comprise the process, but also on other features of the work system, such as the individual, tools and technologies, and environment.

A number of examples of process analysis in health care can be found in a 1997 AHCPR (Agency for Health Care Policy and Research, now known as the Agency for Healthcare Research and Quality) report (Agency for Health Care Policy and Research, 1997). In this report, a total of 15 QI case studies are described and evaluated on Total Quality Management (TQM) principles, such as quality-mindedness, management leadership and continuous improvement. In many of these case studies, the QI teams conducted some form of process analysis to examine issues of, for instance, management of coumadin therapy, and asthma-related emergency room visits.

One possible misuse of process analysis is to 'over-standardize' processes. Many theories of job/organizational design recommend against excessive standardization. The Sociotechnical Systems Theory recommends applying the principle of 'minimum specification' in designing work (Pasmore, 1988). High Reliability Organizations (HRO's) avoid simplification in favor of gaining and providing for a greater understanding of operations (Weick & Sutcliffe, 2001). By recognizing the details and nuances of tasks, a work unit can better anticipate and prepare for an undesired event leading to a potentially bad outcome, regardless of how trivial the outcome may be. Detailed attention to operations, rather than the overall goal, is also associated with less failure. Therefore, it is important to recognize the possible danger of 'over-standardization' and adopt a balanced approach that includes standardization of routine work and minimal specification for non-routine work (Institute of Medicine Committee on Quality of Health Care in America, 2001) (see also section 3.7).

### 3.6 Simulation

Simulation is an umbrella term for methods aimed at attempting to represent reality in various forms. In the context of work (re)design, the following simulation methods may prove useful: simulation of human-machine systems and simulation games. Simulation of human-machine systems involves the development of 'simulators' and are based on computer modeling of human performance (Meister, 1995). Simulators are typically used for training (e.g., patient-simulator used for training of skilled work), and for system evaluation to assess, for instance, a new system design and its potential impact on workload, decision-making, stress and performance. Most simulation involves one or more computers, and relies on computer modeling of human behavior and performance. Meister (1995) categorizes the human performance models into (1) task-network models, (2) control-theoretic models, (3) microprocess models, and (4) cognitive models. Task-network modeling is based on a task analysis. The premise of task-network modeling is that human behavior can be reduced to smaller elements (e.g., "Perform the function, perform the tasks") until a level of decomposition is reached at which reasonable estimates of human performance for the task elements can be made (Laughery & Corker, 1997). This is a top-down approach to modeling human performance. Control theory models or manual control models come from engineering and are oriented toward systems in which tracking plays a major role. According to microprocess models, human performance can be modeled by the aggregation of the internal (micro) processes required to perform the procedures that define the task. These models are 'bottom-up' models, which synthesize larger segments of human performance from a sequence of micro-activities such as bodily movements, reaction times, and recall of events. Cognitive models are problem-solving or diagnostic models in which the behaviors modeled are those involved in, for instance, diagnosing the cause of an illness. More information on computer modeling and simulation can be found in Laughery and Corker (1997).

Meister (1995) has identified a few weaknesses of simulation and human performance modeling. First, the range of behaviors which models address is limited. Second, considerable technical knowledge is necessary to make use of most models. Third, most models are normative and do not adequately describe individual differences or the sources of error in performance. Meister (1995) suggests that human performance models represent tools that can help the system designer to reduce a large number of design options to a more manageable subset for evaluation in mock-ups, simulation games, or experiments. Jha et al. (2001b) describe simulator-based training for various medical specialties, such as anesthesia, radiology, surgery, gastroenterology and cardiology. They warned of the potential risk of simulators to misrepresent human performance and system design, therefore leading to the clinician learning inappropriate behaviors. This emphasizes Meister's (1995) warning regarding the validity of simulation and human performance modeling.

Simulation games can be a useful tool for identifying key areas of work to redesign and to pilot test work redesigns. They provide some structure to the work redesign process, but are flexible enough to adapt to changing conditions. In this context, the word 'simulation' means either model analysis with future users or special experimentation with people or existing case studies. The simulation can be described as a representation of the reality (i.e. a system): it is an abstract, simplified model of a particular system (e.g., a process, administrative practices, team work) (Ruohomaki, 1995). A simulation game is an interactive and participative development method that can be used in various phases of an organizational change process such as work redesign (Smeds, 1997; Vartiainen & Ruohomaki, 1994). Simulation games are action-oriented simulations where the participants jointly simulate their own real work activities (Piispanen, Ruohomaki, Pankakoski, & Teikari, 1996). In general, a simulation game is played by the employees (or actors) involved in the system under study. During the game, employees are together in a room, and simulate their own work activities. The other participants in the simulation game observe the game, and identify and record areas for improvement.

Simulation games can be used to design an 'ideal' process or work system, and test and evaluate necessary adjustments before actual implementation. Simulation games can also be used as a training method. Applications of simulation games in various companies have demonstrated their potential benefits in facilitating organizational change (for example, in administrative work, Piispanen et al. (1996); and in teamwork, Vartiainen & Ruohomaki (1994)).

Several methods for simulation games have been developed for different contexts: work flow game (Ruohomaki, 1995), Softmatch method (Haho and Smeds, 1997), and teamwork game (Vartiainen and Ruohomaki, 1994). Overall, the core elements of the different simulation games are: description of the system (e.g., a work process), preparation of the game session, running the game session, debriefing and evaluation, and follow-up activities. As an example, the different steps of the Softmatch method developed in Finland are shown in Appendix C (Smeds, 1997).

To our knowledge, the methods of simulation game as described in this report have not been applied in healthcare. However, this method could potentially be very useful in healthcare. Many healthcare processes are very complex, require large number of people and organizational units, and ask for collaboration and coordination. Simulation games can be particularly useful for those work processes. Simulation games can be used to identify areas for improvement in a work process and to pilot test a work redesign. Simulation games rely heavily on participation of end-users in designing or redesigning work processes.

### 3.7 Interdependence analysis/variance analysis

An important issue in work (re)design is deciding whether tasks should be combined, and if they should, how to combine them. Many of the theories and models of job/organizational design listed in Table 4 argue for combining tasks and increasing the variety of tasks in a job, either through rotation, enlargement, or some form of enrichment (i.e. job enrichment or enrichment via teamwork). Different methods and guidelines have been proposed for deciding whether/how tasks should be combined. One approach proposed by Davis and Wacker (1987) suggests that tasks get rated on criteria and then these ratings are used to group tasks so that each job or team has a balance of negative and positive tasks. Criteria may include, for instance, the degree of desirability or undesirability, isolated versus collaborative work, and simple versus complex tasks.

Other methods for grouping tasks examine the degree of interdependency or relationship between tasks. The task interdependence analysis proposed by Mohrman et al. (1995) requires the identification of interdependencies between processes, the nature of these interdependencies (e.g., routine or complex, reciprocal or one-way), and the best ways of dealing with these interdependencies. Typically routine interdependencies may be handled by specifications, procedures and standardization, whereas complex and reciprocal interdependencies should be built into a team or some form of collaboration and coordination.

Variance analysis is another method aimed at dealing with interdependencies (Davis & Wacker, 1987; Pasmore, 1988). According to the Sociotechnical Systems Theory, a variance is an unwanted discrepancy between a desired state and an actual state (Davis & Wacker, 1987) or an unwanted or unexpected deviation from standard operating conditions or specifications (Pasmore, 1988). Variance analysis involves the following steps (Davis & Wacker, 1987; Parker & Wall, 1998):

- List all variances that affect the process (e.g., poor quality supplies, breakdowns).
- Identify key variances, i.e. variances that can have serious consequences, interact with other variances, cannot be predicted with certainty, and can be controlled by timely human action.
- Draft a table of key variance control that shows how, where, and by whom each key variance can be detected, corrected, and prevented.
- Construct a table of the skills, knowledge, information, and authority needed for employees to be able to control key variances.
- Redesign work systems so that as many key variances as possible can be controlled at the source.

Ritter and Tonges (1991) show an example of how variance analysis can be used to evaluate the individual needs of intensive care patients and the need to adapt clinical care protocols. In this study, variances are defined as unplanned deviations from the clinical care protocol. Variances are categorized as either positive, i.e. facilitating the patient's recovery and early discharge, or negative, i.e. delaying the patient's recovery and timely discharge.  Four categories of variance were identified: patient (e.g., level of patient commitment and compliance), health (e.g., complications such as infection), caregiver (e.g., caregiver initiating an intervention facilitating discharge) and environment (e.g., ancillary department losing a requisition). On a daily basis, a patient's progress is reviewed in relation to the appropriate protocol, and interventions are implemented to prevent negative variances. Upon discharge, a variance analysis is performed for each patient. These data can then be used by QI multidisciplinary teams to identify opportunities for improvement and implement corrective actions.

A key work design criterion in variance analysis is to provide control and autonomy as close as possible to the sources of variance. A study conducted in manufacturing by Wall and colleagues (1990) shows that a work redesign aimed at increasing operator control led to reduced downtime, and increased satisfaction and less perceived work pressure. Nurses may also benefit from increased autonomy and control over key variances, and nurse performance and patient safety may improve as a result of better control of key variances. Molleman and Van Knippenberg (1995) examined the impact of work redesign on nurses in four units of a hospital in The Netherlands. The work redesign was characterized by the delegation of responsibilities from head nurses to nurses and by increased participation of patients in their care. This work redesign was to provide greater opportunities to nurses to control variances in order to achieve greater flexibility in patient care. The work redesign was evaluated with questionnaires filled out by patients, nurses, head nurses and physicians. The questionnaire data for the four experimental units were compared to data from four control units. Results showed that patients in the experimental groups perceived their nurses to have more control over their stay. Nurses who experienced the work redesign reported greater control and autonomy. In this study, the authors did not examine the impact of the work redesign on patient outcomes, such as patient safety. But, as suggested above, it is very likely that improved control of key variances leads to improved performance, and therefore better, safer patient care.

### 3.8 Ergonomic analysis

Ergonomics is slowly 'creeping' into health care (Jensen, 1999). Ergonomics in health care is very often discussed with regard to occupational safety and health problems, such as work-related musculoskeletal disorders (Evanoff, Bohr, & Wolf, 1999; Punnett, 1987; Stubbs et al., 1983). Ergonomics is also important for obtaining optimal performance and creating the right working conditions for workers to perform their job effectively, efficiently and safely. For instance, in a manufacturing assembly setting, Axelsson (2000) showed that tasks associated with poor working postures accounted for more than 80% of the worker-related errors and approximately 50% of the total assembly quality. In health care, optimal performance will translate into improved quality and safety of care provided to patients. In this section, we discuss three ergonomic issues, i.e. workspace, workstation and physical environment, and ergonomic analysis methods that have been developed to examine and improve workspace, workstation and physical environment. At the end of this section, we describe participatory ergonomics as an 'umbrella' approach to conduct an ergonomic analysis.

#### *3.8.1 Ergonomic design principles*

A number of ergonomic design principles have been developed. For instance, Helander and Willen (1999) developed a series of three ergonomic principles in the context of manufacturing assembly, i.e. minimize perception time, minimize decision time, and minimize manipulation time. Kroemer and Kroemer (2001) proposed three principles for the design of computer workstations: designing for vision, designing for manipulation, and designing for motion. Kroemer et al. (2001) add another principle: designing for human strength.

Table 5 displays a list of the key ergonomic design principles along with specific solutions for implementing those principles. The table also includes examples of how these ergonomic design principles apply tonursing jobs.

#### *3.6.2 Workspace design*

From an ergonomic point of view, designing a physical workspace means arranging components within some physical space (Sanders & McCormick, 1993). The components are physical entities, such as a patient's bed, the nursing station, supply room, patient care equipment such as IV pulls and pumps, wheelchairs, commodes, respiratory therapy equipment, family waiting areas, private conference space, kitchen areas, and medication preparation areas. Ideally, each component would be placed in an optimal location. This optimal location is dependent on the function of the component (what it is used for) and on human capabilities and characteristics, including sensory capabilities and anthropometric and biomechanical characteristics. The goal for designing an optimal workspace is to facilitate performance and reduce the potential for errors.

Sanders & McCormick (1993) have identified four workspace design principles:
(1) *importance principle*. Important components need to be placed in convenient locations. Important components for nursing care include nursing patient care supplies, medical surgical supplies, patient gowns, isolation gowns, gloves and hand hygiene materials, CPR response supplies, and medical sharps disposal container.

(2) *frequency-of-use principle*. Frequently used components need to be placed in convenient locations. They include thermometer, blood pressure cuffs, medical sharps disposal containers and disposable examination gloves.
(3) *functional principle*. Components should be grouped according to their function. For instance, IV supplies should be grouped together because they correspond to the function of IV insertion and line care. Another example is to sort supplies by the body system that the nurse works on.
(4) *sequence-of-use principle.* In performing certain tasks, the worker goes through a specific sequence or patterns of activities. The components should be arranged in order to fit the sequence or pattern of activities. For example, surgical instrument trays or custom packs should be ordered by item sequence use, i.e. urinary catheter insertion kits are arranged by placing sterile gloves on top with the insertion supplies continuing in layers below as required by the steps in the procedure.

The process of designing a new workspace or redesigning an existing workspace typically involves the following steps (Kroemer & Kroemer, 2001):
1. *examination of what nurses need in terms of space*. What tasks will they perform? What equipment will they use or need to have access to? Do they have specific preferences and work styles? How much do nurses need to interact with others (e.g., patient, physician, another nurse)? How much space is individual versus collective?
2. *first specifications by the design team*. The design team includes people with technical knowledge (e.g., architects, ergonomists), and representatives of management and 'end-users'. The design team uses knowledge gathered in the first step in order to define functional requirements of the workspace.
3. *identification of options*. A range of possible options is identified by the design team.
4. *evaluation of solutions*. Criteria need to be defined in order to evaluate the various solutions, such as the workspace design principles of Sanders & McCormick (1993).
5. *implementation of selected design*. Nurses and other affected personnel should be trained on any new equipment or processes that the new design requires.

A number of ergonomic analysis methods are available for designing a workspace. These methods, of course, need data on the components of the workspace (i.e. list of components, frequency of use, relationship to tasks and activities, criticality of components). Another important set of data is on relationships between components, or links. When designing a workspace, one may be interested in many different types of links:

- Communication links: visual (e.g., nurse-to-surgeon, nurse-to-patient's bed), auditory (e.g., nurse-to-physician communication), tactile (e.g., nurse feeling a patient's pulse)
- Control links such as access and use of computer at patient bedside
- Movement links: eye movements (e.g., surveillance of patient in an ICU), manual movements or foot movements (e.g., control of machine by foot pedal), body movements

Link data can be summarized in a link table or in a link diagram (Gramopadhye & Thaker, 1999; Sanders & McCormick, 1993). The columns and the rows of the link table include all components. The link table shows the interaction among the components. For instance, based on direct observations, one may obtain data on the different locations that a nurse walks to during the course of the day. The link table would be created by counting the number of times the nurse goes from one location to another location. Another type of data in the link table could be based on the following proximity rating scale (Sanders & McCormick, 1993): A=absolutely essential, E=essential, I=important, O=ordinary, U=unimportant, and X=undesirable. There are a number of algorithms that exist to optimize links (Drury, 1995). Many of these algorithms have been developed for 'facility layout', and the main criterion is to minimize flow costs by locating facilities optimally (Smith, 2001). Such algorithms can be applied to minimize other outcomes, such as the amount of walking performed by a nurse in between two physical entities. Link data can also be graphically represented in the form of a link diagram. More frequently linked components are represented graphically by greater number of lines shown connecting them. Evanoff and his colleagues have used link analysis to evaluate nursing tasks, track motions and physical connections, and identify heavy traffic patterns (Marshall et al., 2003; Wolf et al., 2003). Their analysis was aimed at identifying possible environmental changes that may be necessary in order to improve efficiency and ultimately patient care and patient safety.

*3.8.3 Workstation design*

The workstation of a nurse will typically be either a computer workstation or a nursing station. There are many design guidelines for computer workstations (Smith & Cohen, 1997; Stanney, Smith, Carayon, & Salvendy, 2001). McHugh and Schaller (1997) describes the ergonomic requirements for a nursing computer workstation. A number of ergonomic analysis methods have been developed to evaluate computer workstations, such as direct measurement, checklist (Cakir, Hart, & Stewart, 1978), videotaping (Cochran, Stenz, Stonecipher, & Hallbeck, 1999), and postural measurement (Corlett, 1995).

The design of standing workstations relies on some of the same ergonomic analysis methods used for computer workstation design, such as postural analysis. An important principle in designing for the standing worker is "Move as much as possible, don't stand still" (Kroemer et al., 2001). The height of the standing workstation depends largely on the activities to be performed with the hands and the size of the objects to be manipulated. In addition, sufficient room should be provided for the feet of the workers, including toe and knee space to move up close to the counter (Kroemer et al., 2001). At a nursing station, so-called stand-seats may be useful to allow the nurse to assume a somewhat supported posture between sitting and standing. Ergonomic methods to analyze standing workstations are similar to the methods used for analyzing sitting workstations: direct measurement, checklist, videotaping and postural assessment (Kroemer et al., 2001).

Analyzing the ergonomic characteristics of a workstation design may require data on working postures. Conducting a postural analysis for evaluating and improving workstation design requires knowledge and skills in ergonomics (Corlett, 1995). However, there are a couple of postural analysis methods that are somewhat easier to learn by non-experts and that have been used in participatory ergonomics groups under the guidance of experienced ergonomists. These methods are called RULA and OWAS. RULA (Rapid Upper Limb Assessment) was developed by McAttamey & Corlett (1993). It uses observations of postures adopted by upper limbs (e.g., wrist twisted or bent, arms above shoulders), the neck (e.g., neck bent), back (e.g., back bent or twisted) and legs (e.g., legs well supported). RULA and OWAS use similar data, either data obtained via direct observations or via videotaping. RULA data are analyzed, and based on the analysis, a number of action levels are defined in a way similar to OWAS. OWAS stands for

Ovako Working Posture Analysis System and was developed in Finland by Karhu et al. (1977). The 84 working postures of the OWAS cover the back (e.g., back bent), arms (e.g., both arms above shoulder level), legs (e.g., standing on both straight legs), and load/use of force (e.g., load/use of force of more than 20 kilograms) (Mattila & Vikki, 1999). OWAS data are gathered via direct observations or using videotaping. OWAS data are then analyzed and produce one of four level of action categories: 1-no actions required, 2-corrective actions required in the near future, 3-corrective actions should occur as soon as possible, and 4-corrective actions for improvement required immediately. Engels et al. (1994) conducted an OWAS-based analysis of nurses' working postures in two units of a hospital. They found some harmful postures and differences in working postures between the two units.

*3.8.4 Physical environment*

Many aspects of the physical environment can affect humans and their performance. Noise, vibration, lighting and climate are of most concern to ergonomists. Noise has been highlighted as a major source of stress and potentially source of error in health care environments (Buemi, Allegra, Grasso, & Mondio, 1995; Topf, 2000). Characteristics of the physical environment are either assessed by direct engineering measurement (e.g., measuring the amount of illumination and noise in a patient's room) or by subjective perceptions (e.g., asking nurses whether lighting is too high or too low for the given tasks being performed and asking whether noise is a source of distraction or discomfort). For instance, evaluating lighting requires examining the following elements: light levels (luminance and illuminance levels, distribution of light, supplementary light), reflectances of various surfaces and equipment, glare, and flicker (Howarth, 1995). The evaluation of lighting entails direct measurement using lightmeters to measure illuminance and luminance meters to measure luminance, observations of the visual environment for glare, flicker and their sources, and questionnaire or interviews to ask the workers about their perception of the lighting environment. Direct measurements (e.g., luminance and illuminance) are typically compared to standards or recommendations (Salvendy, 1997; Wilson & Corlett, 1995).

When deciding on the appropriate levels of various physical environment characteristics (e.g., noise and lighting), it is important to consider the particular tasks being performed. Various standards and recommendations are available depending on the particular characteristics of the task being performed. For instance, tasks that require precision work, such as inserting an intravenous catheter, require a higher level of illumination than computer tasks.

*3.8.5 Participatory ergonomics*

Participatory ergonomics is a powerful method for implementing and sustaining ergonomics program within organizations (Wilson, 1995a). Participation has been used as a key method for implementing various types of organizational changes, such as ergonomic programs (Wilson & Haines, 1997), continuous improvement programs (Zink, 1996) and technological change (Carayon & Karsh, 2000; Eason, 1988). Noro and Imada (1991) define participatory ergonomics as a method in which end-users of ergonomics (workers, nurses) take an active role in the identification and analysis of ergonomic risk factors as well as the design and implementation of ergonomic solutions.

Participatory ergonomics take different forms that can be characterized on the following dimensions (Haines, Wilson, Vink, & Koningsveld, 2002; Wilson, 2000; Wilson & Haines, 1997):

- Permanency: ongoing versus temporary
- Involvement: full direct / partial direct / representative
- Level of influence: entire organization / department or work group
- Decision-making: group delegation / group consultation / individual consultation
- Mix of participants: workers / supervisors / middle management / union / technical staff / senior management
- Requirement: compulsory / voluntary
- Focus: designing equipment or tasks / designing jobs, teams or work organization / formulating policies or strategies
- Remit: process development / problem identification / solution generation / solution evaluation / solution implementation / process maintenance
- Role of ergonomics specialist: initiates and guides process / acts as a team member / trains participants / available for consultation.

Several models and methods have been proposed for implementing participatory ergonomics, such as QI tools and techniques and other problem-solving techniques (Noro & Imada, 1991). Wilson (1991) has developed the 'Design Decision Groups' (DDG) process that uses techniques, such as 'word maps' (e.g., participants are asked to make an inventory of tools and equipment required at their workplace), round-robin questionnaire (e.g., participants are presented with a series of simple open-ended questions such as 'Problems at my workplace are….?'), drawing of one's workplace, layout modeling and mock-ups. Haims and Carayon (1998) have developed a model for the implementation of participatory ergonomics and have conducted several research efforts toward better understanding how to implement effective participatory work redesigns (Carayon, Haims, & Suh, 1997; Carayon, Haims, & Yang, 2000; Haims & Carayon, 1998c). The model asserts that effective participatory programs are developed through continuously providing opportunities for employee involvement linked with feedback and control mechanisms, which leads to continuous learning and the ability of employees to take increasingly higher levels of control over the intervention efforts over time. The model suggests that gradual increases in participation, learning, feedback and control that occur over time allow for the gradual transfer of the participatory program from external regulation by outside experts to internal regulation by organizational members. This model underlines the importance of learning in implementing participatory ergonomics. A case study based on the application of this model is described in section 4.5 and shows the evolving role of the ergonomist. At the beginning of the participatory ergonomics process, the ergonomists provide expertise, knowledge, skills and guidance. The process unfolds so that learning occurs, and, over time, the participants can 'take charge' of the process. This is particularly important in order to sustain change and increase the dissemination of ergonomics within an organization.

Evanoff and his colleagues have conducted studies on participatory ergonomics in health care (Bohr, Evanoff, & Wolf, 1997; Evanoff et al., 1999). One study examined the implementation of participatory ergonomics teams in a medical center. Three groups participated in the study: a group of orderlies from the dispatch department, a group of ICU nurses, and a group of laboratory workers. The form of participatory ergonomics tested in this study consisted of employee-management advisory teams that are a form of labor-management partnership that builds on worker knowledge and problem-solving skills to reduce resistance to change and improve workplace motivation and communication. Training was provided to the team members on team building, basic ergonomic information, and opportunities for application of knowledge. The evaluation of the participatory ergonomics process consisted of surveys handed out to the team members (3 to 5 members per team) about two months and six months after the initiation of the program. Overall, the team members for the dispatch and the laboratory groups were satisfied with the participatory ergonomics process, and these perceptions seem to improve over time. However, the ICU team members expressed more negative perceptions. The problems encountered by the ICU team seem to be related to the lack of time and the time pressures due to the clinical demands. A more in-depth evaluation of the participatory ergonomics program on orderlies showed substantial improvements in health and safety following the implementation of the participatory ergonomics program (Evanoff et al., 1999). The studies by Evanoff and colleagues demonstrate the feasibility of implementing participatory ergonomics in health care, but highlight the difficulty of the approach in a high-stress, high-pressure environment, such as an intensive care unit, where patient needs are critical and patients need immediate or continuous attention.

### 3.9 Allocation methods (responsibility chart-role analysis)

Work design that leads to patient safety problems may involve poor communication and lack of clarity of "who does what" (Helmreich & Merritt, 1998). The responsibility chart is a useful method to determine and clarify task allocation. A number of theories and models of job stress have highlighted the importance of role clarity, such as the Role Theory (Kahn, 1981) and Cooper and Marshall's (1976) model of occupational stress. Creating a responsibility chart involves the identification of who is responsible for what key tasks. The responsibility chart necessitates information and questions on the key tasks: what are the key tasks? Who is responsible for these key tasks? Should the responsibility for the key tasks be changed? If yes, how? The responsibility chart is useful in delineating decision-making responsibilities. Mohrman et al. (1995) have proposed the following rating scale for decision-making: authority to decide, authority to recommend, authority to provide input, need to know, and no involvement.

Another method for understanding "who does what" is to build a role network. A role network is a map of relationships indicating who communicates with a particular role (Hendrick & Kleiner, 2001). A work role is defined as the combination of actual behaviors of a person occupying a position or job in relation to other people. The goal of a role analysis is to understand who interacts with whom, about what, and the effectiveness of these relationships. In a role network, a 'focal role' is identified as the role on which the analysis focuses. A focal role could be, for instance, held by a person who can control key variances in a work process. The role network includes the focal role at the center of the map, and any other roles that relate to the focal role. The length of the lines between the focal role and some other role depends on the frequency and/or importance of particular relationship or interaction between those two roles. Arrows can be added to indicate one-way or two-way communication between two roles. Various rating systems have been developed to further characterize the interactions between the focal role and the other roles (Hendrick & Kleiner, 2001). For instance, one rating scheme defines the type of relationship between two roles: V=vertical hierarchy, E=equal or peer, C=cross-boundary (i.e.

involving another unit or department), O=outside of the organization, and N=non-human component (e.g., a computer).

The role network can then be complemented by additional ratings or data collection aimed at identifying weaknesses and strengths in the interactions or relationships. For instance, the various persons holding the roles can be interviewed about the effectiveness or ineffectiveness of interactions or relationships in accomplishing a certain goal. To our knowledge these allocation methods have not been used in nursing work.

3.10 Work sampling

Work sampling is a key method in the so-called tradition of "scientific study of work" introduced by Frederick Taylor (1911). Other methods closely related to work sampling include work study, time-and-motion study, and time study (Stammers & Sheperd, 1995). Many of these methods were developed at the beginning of the 20$^{th}$ century by people like Frederick Taylor and Frank and Lilian Gilbreth. Over the years, many objections have been raised against Taylorism, which has been seen by some as a tool for over-simplifying work and abusing or exploiting workers. Nonetheless, these methods of work sampling, time-and-motion study and time study are useful for evaluating tasks and work activities (Helander, 1997). It is important to realize that these methods can be valuable tools if used for the right purpose.

Drury (1995) traced the idea of work sampling back to Tippett (1934), who wanted to estimate the proportion of time a worker or a machine was working. In work sampling studies, a worker is observed a number of times at random or fixed time intervals. For each observation, data are recorded on the task being performed. The record includes at a minimum the specific task being performed at that time, and sometimes data on the objective or function of the task and data on who the task is being performed with. When data is recorded on several domains, work sampling are called 'multidimensional work sampling'.

The technique of multidimensional work sampling has been used by Murray and his colleagues (1999) in a study of the impact of a health information system on pharmacists. Multidimensional work sampling was used to determine the percentage of time spent on a variety of predefined activities ("activity"), the purpose of the activity ("function"), and whom the person contacted while doing the activity ("contact"). A similar multidimensional work sampling method was used by Carayon and Smith (2001) in order to evaluate the impact of Electronic Medical Record (EMR) technology on various jobs in a small family medicine clinic in Wisconsin. In this study, data were collected before and after the EMR implementation in order to assess changes in activities, functions and contacts (i.e. three aspects of tasks) due to the EMR. The findings document changes in and the redistribution of workers' and clinicians' duties (e.g., less duplicative paperwork due to one-time computer data collection at the patient's point of entry to the facility), trade-offs in duties based on a manual documentation system versus the EMR (less time spent recording in the paper record and more time spent performing computer entry), and new duties resulting from the new technology (scanning of documents from outside facilities to allow providers access to them electronically). This study disconfirmed the preconceived notion of many of the providers that computerization would increase the amount of time spent charting. In fact, the various activities associated with a paper-based medical record were replaced, to a lesser extent, with data entry and other activities associated with the EMR. In turn, a greater percent of the various providers' time was available and subsequently spent with the patient.

Work sampling data can be used to answer questions such as "What percentage of a nurse's time is spent on direct patient care?" or "What fraction of a clinic receptionist is spent on various activities, such as answering phones, checking-in the patients and so on?" (Kachhal, 2001). McNiven et al. (1993) applied work sampling to intrapartum support. A list of labor nurses' supportive actions was generated based on research findings. The list was limited to supportive actions that were directly observable. The authors of this study argue that work sampling can be used to examine the actual work nurses do. However, in this study, some aspects of what nurses do was not captured with work sampling because not all supportive actions can be observed. This is a major limitation of work sampling when applied to nursing jobs.

Linden & English (1994) conducted a work sampling study to examine time spent by nurses on four categories of tasks: (1) direct care, (2) indirect care (e.g., patient-related communication, preparation for direct care), (3) unit-related activity (e.g., clerical tasks, staff education), and (4) personal time. The initial data collected showed that 27% of nursing tasks was spent on direct care, 42% in indirect care, 15% in unit-related activity and 16% in personal time. When further looking at the data on indirect care, the analysts discovered that a major time-consuming task was looking for someone to relay a message. Another identified problem was that the nursing staff spent nearly as much time completing computer care planning and charting (22%) as with the patient (27%). These observations led to some work redesigns, such as the development of standards of patient care by the nurses and the creation of bedside flow sheets for documentation. The work sampling data, as well as the change process (e.g., involving nurses in the development and implementation of work redesign solutions) led to many improvements, such as reduction of overtime and increased nurse satisfaction. Work sampling, if implemented right for the right purpose may prove useful. However, it is important to realize some of the intrinsic weaknesses of the method.

Work sampling is a method that assumes that the tasks are observable, unambiguous, mutually exclusive and exhaustive (Drury, 1995). Most nursing jobs do not fit all of these assumptions. When observing tasks performed by a nurse, the analyst records only what is seen, not what is inferred. Thus, 'thinking', 'planning', etc… all look very similar to the analyst. In such cases, the analyst should record 'no task seen' (Drury, 1995). Tasks that are recorded need to be mutually exclusive. However, very often, a nurse may be doing more than one task at a time: for instance, taking vitals on a patient and observing the physical status of the patient. The analyst is supposed to record only one task, but in some cases, s/he may have to record that multiple tasks are being performed at the same time. A major issue in work sampling is to come up with an exhaustive list of tasks to be observed. The better the analyst knows the job to be observed, the better s/he can anticipate all possible tasks. An 'other' category may be needed, but if many similar observations fall into that category, additional categories of tasks need to be created. Carayon and Smith (2001) used the following steps in order to develop the list of tasks for their multidimensional work sampling study. First, all position descriptions were gathered. Second, information on tasks contained in the position descriptions was extracted to develop a draft list of tasks. Third, the draft list was shared with people representing the different jobs to be observed in order to ensure that the list was complete and had mutually exhaustive tasks as much as possible. Fourth, the list was modified based on that input, and then pilot tested. Fifth, further modifications were made to create the final list of tasks.

Drury (1995) argues that the analyst collecting and analyzing work sampling data needs to understand the work being observed in order to develop a valid, useful set of tasks or other entities to be observed. When performing a work sampling analysis, a number of decisions must be made that greatly influence the data collected and its quality. For instance, the interval between readings and the observation schedule (i.e. random or fixed-interval) are important variables.

One possible misuse of work sampling is in simplifying work and work processes. Given that work sampling was created by Frederick Taylor and colleagues, it is of no surprise that work sampling data may lead 'naturally' to work simplification. This is contrary to most theories and models of job stress and job/organizational design that recommend increased task variety (see tables 3 and 4).

3.11 Implementing a work (re)design project

Whereas we have presented two possible structured systematic work design processes (see Figures 2 and 3), it is important to recognize that such a process needs to be *flexible*. Many changes may occur during the work design process, such as iteration around loops in the process, redefinition of the objectives, and changes in criteria and priorities (Wilson 1995). However, it is also important to recognize the variety of activities that need to take place when (re)designing work.

The two different work design processes described in section 3.1 (Figures 1 and 2) have characteristics similar to the PDCA (Plan-Do-Check-Act) cycle of quality improvement (Deming, 1986). The process of work (re)design can be considered as a quality improvement process. Work design uses some of the same methods as QI. For instance, Noro and Imada (1991) describe the use of PDCA and various QI tools in the context of ergonomic (re)design of workspace and workstation. In section 3.5, we described how one of the main QI tools, i.e. process analysis, can be used in work design. There are many similarities between QI and work design. However, one should remember that work design considers the individual as the center of the system. Work design is very much a 'people-oriented' discipline that involves end-users, collects data from end-users, and proposes redesigns aimed at improving work for end-users (e.g., facilitating their performance and improving working conditions).

The process of work redesign needs to be managed like any organizational (or technological) change project (Kovner, Hendrickson, Knickman, & Finkler, 1993). The way change is implemented (i.e. the process of implementation) is central to the successful adaptation of organizations to changes (Korunka, Weiss, & Karetta, 1993; Tannenbaum, Salas, & Cannon-Bowers, 1996). A 'successful' work redesign effort can be defined by its 'human' and organizational characteristics: reduced/limited negative impact on nurses (e.g., stress, dissatisfaction, etc) and on the organization (delays, costs, reduced performance, etc), and increased positive impact on people (e.g., acceptance of change, job control, enhanced individual performance) and on the organization (e.g., efficient implementation process, improved patient safety). Various principles for the successful implementation of work redesigns have been defined in the business and industrial engineering research literature.

*Employee participation* is a key principle in organizational change (Coyle-Shapiro, 1999; Korunka et al., 1993; Smith & Carayon, 1995). There is research and theory demonstrating the potential benefits of participation in the workplace. Benefits include increased employee motivation and job satisfaction, enhanced performance and employee health, more rapid implementation of technological and organizational change, and more thorough diagnosis and solution formation for ergonomic problems (Gardell, 1977; Lawler III, 1986; Noro & Imada, 1991; Wilson & Haines, 1997). The manner in which a new work redesign is implemented is critical (see for example Eason (1982), Carayon and Karsh (2000) and Smith and Carayon (1995)), and end user participation in the design and implementation of the new work redesign is a good way to help ensure a successful outcome. Korunka and his colleagues (Korunka & Carayon, 1999; Korunka et al., 1993; Korunka, Zauchner, & Weiss, 1997) have empirically demonstrated the crucial importance of end user participation in the implementation of technology to the health and well-being of end users. One can distinguish between *active participation*, where the employees are actively participating in the implementation of the new work redesign, from *passive participation* where the employees are *informed about and communicated with* regarding the new work redesign (Carayon & Smith, 1993).

Redesigning work for improving patient safety involves many different people: the nurses whose jobs are being redesigned; the patients who are being taken care of by those nurses; the physicians, pharmacists and other healthcare professionals who work with those nurses; the various support staff personnel (e.g., QI/QA, human resource management, facility planning, purchasing, information systems); and various other caregivers. The people who are either directly or indirectly affected by the work redesign are 'stakeholders' who in some way should be involved in the process (Stachura, 1998). In addition, involving the nurses directly affected by the work (re)design as early as possible can contribute to increasing their commitment to the project (Kovner et al., 1993).

Work (re)design should also be considered as a continuous process. Work changes because people doing the work change, technologies change, physical facilities are redesigned, new procedures and structures are implemented, etc… Therefore, the work system is a highly dynamic system that needs to be continuously evaluated and improved. The QI principle of continuous improvement is very relevant for work design (Deming, 1986).

Work redesign should be considered as an evolving process that requires considerable *learning* and adjustment (Mohrman et al., 1995). The participatory process model developed by Haims and Carayon (1998b) specifies the underlying concepts of the learning and adjustment, i.e. action, control and *feedback*. The importance of feedback in managing the change process is also echoed in the literature on quality management (see, for example, the Plan-Do-Check-Act cycle proposed by Deming (1986)). Feedback is an important element in order to change behavior (Smith & Smith, 1966), and has been emphasized as an important organizational design element in the healthcare literature (Evans et al., 1998; McDonald, Overhage, Tierney, Abernathy, & Dexter, 1996). An aspect of learning in the context of job/organizational change is the type and content of *training* (e.g., Frese et al., 1988; Gattiker, 1992).

Studies have been performed that examine the characteristics of successful change processes in industrial settings. For example, Korunka and Carayon (1999) examined the implementation of information technology in 60 Austrian companies and 18 American companies. Compared with the Austrian implementations, the American implementations were characterized by a higher degree of professionalism (e.g., more use of *project management* tools) and more participation, but at the same time by more negative effects for employees (e.g., personnel reduction).

In summary, the principles for a successful work redesign process are as follows:

- *employee participation*: extent to which nurses are involved in various decisions and activities related to the work redesign project
- *information and communication*: extent to which nurses are kept informed of the work redesign implementation through various means of communication
- *continuous improvement*
- *training and learning*: extent and nature of the training provided to the nurses and extent of learning by the nurses
- *feedback*: extent to which feedback is sought after during the work redesign implementation
- *project management*: activities related to the organization and management of the work redesign implementation itself.

## 4. Examples inside/outside of health care

Five case studies are described in this section: three from health care and two outside of health care. These case studies tackle issues of hospital facility design (St Joseph's hospital), organizational structure (Magnet hospitals), teamwork in an emergency department, cellular manufacturing, and participatory ergonomics.

4.1 Facility design – St Joseph's hospital

Health care facility construction, whether a new building or an expansion of an existing medical center, can present a number of challenges and a number of opportunities, not the least of which is improving working conditions, quality of care and patient safety. However, a far-sighted health care facility in West Bend, Wisconsin is demonstrating that new construction projects actually present an opportunity to improve working conditions and patient safety.

Although there is currently no published scientific literature on the association between health care facility design and patient safety and nurses' working conditions, the environmental impact on job design and safety is well documented. Norman (1988) reports that humans do not always behave clumsily and humans do not always err, but are more likely to do so when things they use or environments they work in are poorly conceived and designed. Additionally, Moray (1994) points out that well intentioned, skilled health care providers may be forced to commit errors by the way in which the design of their environment may call forth behaviors leading to errors. The impact of the environment design on work and work processes is self-evident. The movement of materials, movement of patients, the way nurses and patients see each other, clinical processes, etc… are heavily influenced by the facility and the equipment contained within (Reiling & Chernos, 2004).

In April 2000, St. Joseph's Community Hospital of West Bend, Wisconsin, a member of *Synergy*Health Inc., started focusing on how the design of a new facility could affect patient safety. A participatory learning laboratory developed recommendations that St. Joseph's could apply in the design process (Reiling & Chernos, 2004). Although the 13 design principles do not include nursing work (re)design, many of the principles have a unique impact on patient care activities and should be evaluated using the work system approach described in section 2.2. Demands are placed on the individual (nurse) by the environment, the task requirements, the organizational structure and the technology used (Smith & Carayon, 2000; Smith & Carayon-Sainfort, 1989).

In this case study, facility design is used to promote patient safety. The following St. Joseph's learning lab design recommendations can affect many different elements of nurses' work.

*Standardization* of the facility and room design, from location of room electrical outlets to bed controls, equipment cupboards, medical equipment such as IV pumps to hand decontamination products and sinks, location of medical gases, monitors, etc… will probably reduce the likelihood of error. The standardization of patient care environments and equipment greatly decreases the cognitive load on the nurses, making routine tasks less likely to cause slips and lapses. This standardization of the workspace fits with many of the ergonomic design principles listed in Table 5, such as minimizing decision time and manipulation time. Ergonomics recommends that a new workspace or tool should be designed to be similar to the old in order to facilitate transfer of training.

*Visibility of patients to staff* allowing close proximity of nurses to their patients all them to be more efficient and effective in delivering care (Drake, 2001).Visibility allows the nurse to see changes in the patient, attention to the patient's equipment, decreases the risk of falls when patients attempt to get in or out of bed without assistance.Visibility can also enhance a patient's or a family's feeling of well-being – knowing that the nurse is always within sight, or close at hand. Having the nurse close to the patient shortens and often eliminates the constant traffic of nursing units. Additionally, it facilitates nurses sharing of tasks that may be difficult for the lone nurse such as patient lifting or movement of cumbersome patient care equipment.

*Automate where possible* is a concept brought to the forefront in the 2001 IOM report (Institute of Medicine Committee on Quality of Health Care in America, 2001). Technologies such as bar-coding technology, electronic medical records, and clinical decision support systems have profound effects on the work of nurses. However, when designing the new health care facility, the technology planning should begin very early in the process as it has a tremendous impact on the nurse and his/her work. Lack of adequate skills to use the new technology, physical load placed on the nurse to use this technology, and the effects of the patient care environment on this new technology all must be taken into consideration in the automation design phase (Carayon & Smith, 1993, 2000; Smith & Carayon, 1995).

*Bringing decision making information close to the patient* such as hand-held laptops and personal digital assistants allows the nurse to chart, document patient education, and look up medical data. Other tools may be needed to support nurses' work at the patient's bedside. This may allow more time to be spent on direct patient care (Baldwin, 2002). Bringing the information closer to the patient helps the nurse in patient education and better articulation of the patient's individual views and preferences in their care (Deyo, 2002).

*Noise* is now being recognized as a serious health hazard and threat to safety and performance (Buemi et al., 1995; Topf, 2000). Noise is one of the most well-known environmental stressors that can cause increases in arousal and blood pressure and negative psychological mood (Cohen & Spacapan, 1984; Smith & Carayon-Sainfort, 1989). There are two key considerations in reducing noise in the health care setting. First, manage the source of the noise which includes elimination of overhead paging, proper insulation of HVAC systems, plumbing, ice machines etc… and proper management of equipment alarms. The need to page the nurse and the need to be alerted to equipment alarms has a direct effect on the nurse's work and how it is performed. The second consideration is to reduce noise by installing materials that absorb sound such as ceiling and wall materials and carpeting. The consideration of changing environmental materials must take into account the maintenance of these the materials and whether the nurse will assume a greater workload given the new sound-reducing materials.

*Minimize fatigue* has been identified as a possible solution to reduce human error and improve patient safety. Although research has not yet proven the effects of fatigue on patient safety, studies have shown fatigue has a negative impact on alertness, mood and psychomotor and cognitive performance (Grandjean, 1980; Kroemer & Grandjean, 1997); all of which can have an impact on patient safety (Gaba & Howard, 2002; Gander, Merry, & Millar, 2000; Jha, Duncan, & Bates, 2001a). In facility design, minimizing the distances nurses must travel between patient rooms, nursing stations and treatment areas, could not only effect the number of patient rooms per floor but also the vertical and horizontal adjacencies of departments (Reiling & Chernos, 2004).

Many tools are available to reduce human error, enhance patient safety, and redesign work through new facility development. These tools include Failure Modes and Effect Analysis (FMEA) both for processes and designs, design teams and mock ups. At each step of the hospital facility design, an FMEA can be performed, focusing not just on the departmental process and the organizational process but also on the effects to the individual care providers' work loads. St. Joseph's Community Hospital's patient safety culture is evolving as a result of this safety-focused facility design. As the design progresses, much more will be learned about this important concept for promoting the kinds of changes in nurses' work environments that are essential to continued job satisfaction and patient safety.

The impact of the new facility design as well as the implementation process has not been formally evaluated yet. However, a few key principles can be highlighted. This case study shows that facility design can affect many different aspects of work besides the physical features of work. When designing a facility for improved patient safety, other elements of work may need to be redesigned, such as the tasks and tools and technologies used to perform those tasks. The facility design process used by St Joseph's hospital is one that involves many stakeholders, including nurses.

4.2 Magnet hospitals

In 1982, the American Academy of Nursing's Task Force on Nursing Practice in Hospitals conducted a study of 41 hospitals to identify and describe variables that created an environment that attracted and retained well-qualified nurses (McClure, Poulin, Sovie, & Wandelt, 1983). These institutions were called "magnet" hospitals as they were thought to serve as "magnets" attracting and retaining nurses who experienced a high degree of professional and personal satisfaction through practice at these institutions. Over the past decade, hospital nursing service utilization, based on the results of the 1982 magnet study, has been used in many changes and innovations in nursing systems (Aiken, 2002).

The magnet hospitals share a set of organizational attributes namely (Havens & Aiken, 1999):

- The nurse executive is a formal member of the highest decision-making body in the hospital, which signifies the high priority placed on nursing.
- Nursing services are organized in a flat organizational structure with few supervisory personnel.
- Decision making is decentralized to the unit level, giving the individual nurse on the unit as much discretion as possible for organizing care and staffing in a manner most appropriate to the patients' needs.
- Administrative structures support the nurses' decisions about patient care.
- Good communications exists between nurses and physicians.

The nurses' work system in magnet institutions demonstrates three distinct core features (Havens & Aiken, 1999):

- Autonomy over practice
- Nursing control over the practice environment and
- Effective communication between nurses, physicians and administrators

The Job Characteristics Theory of Hackman and Oldham (1976) emphasizes five critical elements to any job (see Table 4): skill variety, task identity, task significance, autonomy, and feedback. The job design characteristics lead to employee feelings of meaningfulness, responsibility, and knowledge of results. In other words, jobs that facilitate higher level outcomes of the five job characteristics would result in higher order need attainment, increased job satisfaction, and increased productivity (Flarey, 1991). Additionally, Herzberg's (1974) motivation approach to job design has been advocated for use in nursing (Vestal, 1989). The intrinsic and extrinsic factors associated with this approach (i.e. autonomy, skill requirements, communication, achievement, task significance, feedback, recognition and pay adequacy) and the job characteristics of Hackman and Oldhman's theory appear to be influential in defining the roles of nurses in magnet hospitals.

However, just as the original job design and job enrichment theories by Hackman and Oldham (1976) and Herzberg (1974) lack a system perspective to work design (Smith & Carayon-Sainfort, 1989), so does the magnet hospital approach to job design lack a holistic perspective. Although the magnet hospital approach attempts to address the unique work of nursing and makes suggestions for work design improvement, it lacks the integration of the five elements of the work system model (Smith & Carayon-Sainfort, 1989). In the Balance Theory of Carayon and Smith (see section 2.2), there are categories of "loads" that work can exert on the individual (nurse). The magnet hospital concept addresses various solutions to these working conditions for two elements of the work system.

With regard to the work of nursing, the magnet hospital concept is highly vested in the *task* and *organization* elements of the work system model. The task element is represented by the movement towards all Registered Nurses (RN) staffing, cross-training to provide multi-skilled personnel and recommendations of nurses with advanced degrees providing research background for evidence-based practices. The organization element of the work system is reflected by the increasing ratios of RN to patient, flattening of the organizational structure, implementing salary status as opposed to hourly wages, implementing flexible and varied nursing care delivery models designed to meet the changing needs of patient and staff throughout the organization and improved communications between nursing and medical professionals (Havens & Aiken, 1999). The two other elements of the work system model, *tools and technologies*, and the *physical environment*, have gone unnoticed in the magnet hospital approach. Magnet hospital core concepts such as decentralized decision making to the unit level, giving the individual nurse on the unit as much discretion as possible for organizing care, staffing in a manor most appropriate to the patients' needs and good communication between nurses and physicians are carried out in a physical environment and require tools and technologies to be effectively implemented. Unless all elements of the work system are considered when implementing the magnet core concepts, a misfit or imbalance in the work system can occur. As an example, augmenting information technology may enhance patient care and nursing communication, but its implementation must take into consideration the loads placed on the individual nurse, given the environment this tool or technology is used in and the ease of training and acclimation this new technology requires in order to reduce these perceived loads.

Current health care is characterized by the search for best practices, quality targets, and excellence in a professional working environment. Attaining magnet hospital status is perceived as a prime advantage to nursing job design (Aiken, 2002). However, the concept of magnet hospital nurse work design can benefit from the interplay among the various elements of the work system, providing more direction to balance the positive elements over the negative elements in the nurses work design.

### 4.3 Teamwork in emergency department

Morey et al. (2002) report on the implementation of teamwork in emergency departments and its impact on error reduction and performance improvement. The work redesign had two components: (1) teamwork training, and (2) institutionalizing teamwork. The teamwork training curriculum was developed based on Crew Resource Management (CRM) principles (Helmreich & Merritt, 1998; Salas et al., 1999). Physicians, nurses and technicians in emergency departments of 6 hospitals were trained on CRM. The training curriculum was organized around five team dimensions: (1) maintain team structure and climate, (2) apply problem-solving strategies, (3) communicate with the team, (4) execute plans and manage workload, and (5) improve team skills. Following the training, a formal teamwork structure was implemented. A team was comprised of 3-10 members, including physicians, nurses and technicians. The implementation of this new work redesign necessitated various changes to the work system and work processes.

The effectiveness of the intervention (training + teamwork implementation) was measured with three types of outcomes: team behaviors, attitudes and opinions, and ED performance (including observed clinical errors). After the teamwork implementation, there were significant improvements in staff attitudes toward teamwork. However, the improvement in teamwork behavior was not achieved at the expense of increased workload. This is particularly important because work redesigns are often accompanied by increased workload and work pressure (Carayon, Sainfort, & Smith, 1999; Wall, Kemp, Jackson, & Clegg, 1986). Data also showed that the number of observed clinical errors went down significantly in the teamwork-trained emergency departments as compared to the control group of emergency departments. Another significant finding of this study was that the positive impact of the intervention was maintained to a large extent about 8 months after the training. The teamwork intervention was effective in each of the three domains evaluated in the study.

The authors of the case study emphasize that training the physicians, nurse and technicians was only the first step of the intervention. The training was well received, but implementation of a formal teamwork structure necessitated considerable effort and time from the part of the stakeholders. This underscores the importance of the process or plan for implementing work redesigns (see section 3.11).

This teamwork intervention can be conceptualized as a change in the *organizational* element of the work system. Two organizational elements were targeted in this work redesign: training and formal team structure. This change in the organizational element of the work system led to major changes in the *tasks* performed by the physicians and nurses: who is doing what? how? Qualitative findings emphasize the importance of leadership at the operational and organizational level in the successful implementation of the teams. This underlies the importance of having *organizational conditions* aligned with the rest of the work system. Other important organizational issues highlighted in this case study include instituting a reward structure for teamwork, and the need for continuing or refresher training. Morey et al. (2002) make some interesting remarks on changes in the *physical environment* because of the implementation of teamwork. For instance, some of the EDs redesigned their physical layout in order to foster and accommodate teamwork. These redesigns in the physical environment were made in order to reduce barriers between physicians and nurses, and therefore promoting information exchange among the team members.

This case study shows that an intervention aimed at teamwork (i.e. CRM training and implementation of formal teamwork structure) represents a major change in the organizational element of the work system. This change was accompanied with many other changes in the work system, such as the tasks and the physical environment. In addition, the case study shows the importance of aligning various organizational sub-systems, such as training, reward structure and management support. This fits with Lawler's High-Involvement Management principles of power, knowledge, information and rewards (Lawler III, 1986).

4.4 Cellular manufacturing

Parker and Jackson (1993) present the case of an electronics company that went through a major work re-organization of its production process. The manufacturing facility produces printer circuit boards that are used in control equipment for a variety of process industries such as chemicals, nuclear power and oil. A number of problems regarding performance within production itself faced the company:

- poor quality yield, i.e. only 70% of fault-free products
- long production time
- poor delivery integrity, i.e. getting the right product to the customer at the right time
- unbalanced work flow with large stocks of work awaiting completion at different stages of production
- assembly workers' perception of quality not being their responsibility
- low commitment by workers
- very little cross-training of workers.

Before the redesign, production was organized functionally. The first stage of production is kitting where all the components required for a job are assembled according to specifications. From there, work goes on to first-phase manual assembly, where unusual components are placed by hand. Boards are then transferred on a trolley to the flow-solder area, where solder connections are made. Boards are returned to the manual assembly area for second-phase manual assembly, where large components are inserted and soldered in place. An initial quality audit is conducted at this stage by inspectors. The next stage is an in-circuit test using automatic test equipment. The board is then tested within the run-in area. Then functional tests are completed. Finally, boards are moved to final quality audit, then either stored or shipped to customers.

In response to many of the production problems, the company decided to re-organize production and work into product lines (Talavage & Hannam, 1992; Wemmerlov & Hyer, 1992). This redesign included the following elements:

- Production was re-organized into five product-based cells (i.e. product lines). Each cell manufactures a specific type of product.
- Each cell performs all production tasks, i.e. stores, kitting, assembly, quality audit/inspection and testing. Cross-trained workers perform the tasks.
- The functions of quality audit, inspection and routine maintenance are the responsibility of the cells.
- Each cell operates as a self-managing team supported by a 'team manager'. The entire team is responsible for meeting production targets.
- The layout of the shopfloor was completely redesigned. The new layout allowed for each of the cells to have its own physical space with all the equipment and machinery necessary. Because of its high cost, the flow solder equipment is the only equipment shared by all cells.

The process for implementing this major work redesign unfolded over almost two years. As a first step, top management decided to form a pilot team in order to examine the feasibility of the redesign. Initially, the pilot team members expressed a great deal of enthusiasm and commitment. However, very quickly, a number of problems emerged. First, the enthusiasm and commitment of the pilot team was not matched by that of the rest of the facility. The pilot team needed support from various parts of the facility, and had a very hard time in obtaining it. Second, initial training was not optimal. Team members realized that the technical skills needed to perform the newly assigned tasks could not be acquired in a few weeks. However, a survey conducted one year after the initiation of the pilot project showed that the pilot team members had been able to work out many of the issues. Over time, they became more skilled at performing the various tasks assigned to the cell, developed a better capacity at self-managing themselves, and had a clearer understanding of what was expected from them. Performance dramatically improved, including reduced lead time (from 7 days for one system to 10 per week), reduced defects and improved delivery integrity (from delivering the right products on time about 33% of the time to about 80% of the time). Pilot team members had a greater sense of ownership for the products, the production process and meeting the targets. Because of the success of this pilot project, management decided to proceed with the next stage of implementation, i.e. implementation of product lines across the whole of manufacturing.

This case study shows that a work redesign such as cellular manufacturing involves changes in many different aspects of work, and that considering all of these aspects of work is critical in the success of the work redesign. The process for implementing the new cellular manufacturing system relied on worker involvement, provision of adequate resources (e.g., training, top management support) and a pilot test. The pilot test was particularly important because it allowed the company to examine the feasibility and performance impact of the new redesign before deploying it to the rest of the company. In addition, the pilot test allowed the company to 'iron-out' all the issues and concerns related to the implementation of the new redesign. The case study also shows the importance of 'time'. Time is necessary for the company to try the redesign (pilot test), for the workers to learn new skills and be fully cross-trained and proficient at all tasks, and for the redesign to have its fullest impact on performance.

## 4.5 Participatory ergonomics in office/computer work

Haims and Carayon (1998a) describe a case study on participatory ergonomics in office/computer work using the work system model of Carayon and Smith (Carayon & Smith, 2000; Smith & Carayon-Sainfort, 1989). Several work areas of a public service agency in the Midwest participated in the study. They consisted of jobs in data and word processing and data entry. The jobs required an average of 7.2 hours of computer use per day, and approximately 85% of the jobs were occupied by female employees.

The methodology used to identify the key ergonomic problems and propose and implement solutions had the following characteristics:

- *Action-research*. To meet both research and practical goals, an action-research framework was used (Israel, Schurman, & Hugentobler, 1992; Susman & Evered, 1978). Planning, action, intervention and learning were shared by both researchers and organizational members.
- *Time*. Data were collected at multiple data points in order to study the effects of the redesigns over time, and make any necessary adjustments.
- *Actors*. Multiple participants at different levels/units in the organization participated in the study in order to ensure representativeness of and input from concerned parties.
- *Methods*. Multiple data collection methods were used in order to obtain valid and reliable data.
- *Study variables*. A range of work system variables were examined in order to have a complete overview of problems and possible solutions.
- *Participatory ergonomics*. Employees participated in the identification of ergonomic problems and in developing and implementing ergonomic solutions.
- *Train-the-trainer*. A group of selected employees (i.e. ergonomic coordinators) were trained by the research team to train other employee groups. This strategy was used in order to quickly disseminate ergonomic information throughout the organization, involve employees, and enrich their jobs.

Seven data-collection methods were used during the course of the study. A questionnaire survey was administered at the beginning of the study and then about every year during the study. This comprehensive questionnaire survey was developed by the research team and included many standardized questions and scales used by the research team and other researchers. This allowed for benchmarking the data collected in this organization to data collected in other organizations on similar jobs. Ergonomic evaluations were initially performed by the research team. Over time, many of the ergonomic measurements were taken over by the ergonomic coordinators. Videotaping and observational methods were used to provide information on tasks, postures, and pace. Individual interviews with employees, supervisors and other personnel (e.g., safety manager) were conducted to verify results from other data collection methods and tap employee perceptions (e.g., comparing and contrasting measurement of the lighting conditions to employee perceptions of the adequacy of lighting). Company records, such as worker's compensation claims and performance data, were examined pre- and post-redesign to assess needs and redesign effectiveness. Feedback evaluation forms were used as means for continuous feedback of the participatory ergonomic process. Ergonomic coordinators were regularly surveyed on the effectiveness and impact of the process. Finally, the research team kept a diary record of the activities, timeline, redesigns, and organizational reactions, outcomes and impact.

The ergonomics program was initiated with a 2-day training of volunteer employees (so-called ergonomic coordinators) (Hajnal & Carayon, 1994). Topics covered in the training included an overview of ergonomics, aspects of the physical environment, musculoskeletal problems in computerized offices, and specific workstation design and work practice changes that could be implemented in their own local environment. The questionnaire survey conducted shortly after the initial training of the ergonomic coordinators showed very little improvement in working conditions and overall performance and well-being. A follow-up session was held with the group of ergonomic coordinators, and a need was expressed regarding a more developed ergonomics program ('not just training'), regular meetings, and more practical information and training for enhanced communication capabilities. The revised ergonomics program unfolded over a one-year period. During this time, the research team and the ergonomic coordinators met on a regular basis. Hands-on training was conducted, continuous feedback was solicited from the ergonomic coordinators, and planning for the future (i.e. after the research team has left) was emphasized. A total of 13 ergonomic coordinators participated in this revised phase of the ergonomics program, representing about 450 employees within the organization.

The outcomes of this process were evaluated with both quantitative and qualitative data and inputs from the ergonomic coordinators, as well from the employees represented by the ergonomic coordinators. Feedback evaluation forms filled out by the ergonomic coordinators displayed increases in overall usefulness of the program and usefulness of skills learned in the program. Results of the interviews showed improved communication and learning, and a greater capacity of the ergonomic coordinators to successfully address organizational barriers in the implementation of various ergonomic recommendations. Questionnaire data showed many improvements in working conditions as perceived by the employees, as well as decreased upper body discomfort and hand/arm discomfort. It is also important to realize that, even after the departure of the research team, the ergonomic coordinators continued their work. The research team continues to receive emails from the ergonomic coordinators. The ergonomics program that was initiated with much input and effort by the research team became a program internal to the organization.

In this case study, the focus of the work redesign was on the physical aspects of work, but the implementation process had many psychosocial characteristics of importance in the job stress and job/organizational design literature. For instance, employee participation, opportunities for learning and skill enhancement, and enhanced networks for social support were some of the characteristics of the implementation process that promoted active participation of the employees, as well as their acceptance of the work redesigns. A variety of data collection methods were used to collect data from multiple sources at multiple points in time. These data were used for (1) identifying the 'negative' aspects of work (to be redesigned), (2) continuously evaluating the participatory ergonomics process, and (3) assessing the impact of the work redesign. In this case study, the presence, involvement and strong guidance of the ergonomists were critical at the beginning of the process. However, over time these became less important mainly because of the transfer of skills and the learning of the ergonomic coordinators. This process took time to unfold: it needed feedback and practice in order to occur.

## 5. Recommendations to healthcare decision-makers

Based on the information presented in the previous sections and the specific lessons learned from the case studies, we propose a series of specific and general recommendations to healthcare decision-makers for how to approach work (re)design. Below is a set of key principles for successful work (re)design. The rest of this section addresses general recommendations for work design.

KEY PRINCIPLES FOR SUCCESSFUL WORK (RE)DESIGN

Several authors have proposed design principles and best practices for the process of implementing work (re)design processes (Carayon, 1994; Carayon, Haims, & Suh, 1999; Haims & Carayon, 1998a, 1998b; Kovner et al., 1993), and together they represent a 'toolbox' for work design professionals and healthcare administrators and managers to use in the field. The subsequent list by no means is all-inclusive, but rather represents what these authors have expressed as key components for effective, continuous improvement work (re)design processes:

- Use a systems approach to work (re)design, such as the Balance Theory of work design (see section 2.2).
- Collect data for identification of problems and identification of criteria and goals, and use multiple data-collection approaches (see sections 3.2 to 3.10 for various work design methods).
- Include all key stakeholders in the process, along with those who bring the necessary knowledge, skills and perspectives 'to the table' (see section 3.11).
- Develop a staged process plan, including analysis, synthesis, evaluation and continuous improvement phases (see section 3.11).
- Strike a balance between structure (e.g., project management and adhering to the process plan) and flexibility (e.g., making necessary changes along the way) (see section 3.11).
- Ensure the necessary resources are available to carry out the process plan (see section 3.11).
- Secure 'buy-in' and commitment (including time) from top management and other key stakeholders (see section 3.11).
- Share information by communicating all process plans to stakeholders and people directly or indirectly affected by the work design process (see section 3.11).
- Incorporate individual and organizational learning into the process (see section 3.8).
- Adhere to established training principles, such as experiential learning through action, feedback and feedback control and staged levels of learning (see sections 3.8 and 3.11).
- Be a flexible, dynamic outside expert willing to wear many different hats throughout the process of intervention development and implementation (see section 3.8).

### 5.1 Role of technology

In healthcare the role of technology in improving patient safety has been very much emphasized (Bates et al., 1998; Bowies, 1997; Institute of Medicine Committee on Quality of Health Care in America, 2001; Kohn et al., 1999; Leape, 1994). Is the role of technology being overemphasized? It is important to recognize that technology is only one element of the work system. When looking for solutions to improving patient safety, technology may or may not be the only solution. For instance, a study of the implementation of nursing information computer systems in 17 New Jersey hospitals showed many problems experienced by hospitals, such as delays, and lack of software customization (Hendrickson, Kovner, Knickman, & Finkler, 1995). On the other hand, at least initially, nursing staff reported positive perceptions, in particular with regard to documentation (more readable, complete and timely). However, a more scientific quantitative evaluation of the quality of nursing documentation following the implementation of bedside terminals did not confirm those initial impressions (Marr et al., 1993). This later result was due to the low use of bedside terminals by the nurses. This technology implementation may have ignored the impact of the technology on the tasks performed by the nurses. Nurses may have needed time away from the patient's bedside in order to organize their thoughts and collaborate with colleagues (Marr et al., 1993). This study demonstrates the need to understand the impact of technology on the other elements of the work system.

Technologies can change the way work is being performed and because healthcare work and processes are complex, negative consequences of new technologies are possible (Cook, 2002). Whenever implementing a technology, one should examine the potential positive AND negative influences of the technology on the other work system elements (Battles & Keyes, 2002; Kovner et al., 1993). In a study of the implementation of an Electronic Medical Record (EMR) system in a small family medicine clinic, a number of issues were examined: impact of the EMR technology on work patterns, employee perceptions related to the EMR technology and its potential/actual effect on work, and the EMR implementation process (Carayon & Smith, 2001). Employee questionnaire data showed the following impact of the EMR technology on work. Increased dependence on computers was found, as well as an increase in quantitative workload and a perceived negative influence on performance occurring at least in part from the introduction of the EMR (Hundt, Carayon, Smith, & Kuruchittham, 2002). It is important to examine for what tasks technology can be useful to provide better, safer care (Hahnel, Friesdorf, Schwilk, Marx, & Blessing, 1992).

The human factors characteristics of the new technologies' design should also be studied carefully (Battles & Keyes, 2002). An experimental study by Lin et al. (2001) showed the application of human factors engineering principles to the design of the interface of an analgesia device. Results showed that the new interface led to the elimination of drug concentration errors, and to the reduction of other errors. A study by Effken et al. (1997) shows the application of a human factors engineering model, i.e. the ecological approach to interface design, to the design of a haemodynamic monitoring device. Experimental studies with intensive care nurses and nursing students showed the positive impact of the new interface design on speed and accuracy of readings.

The new technology may also bring its own 'forms of failure' (Battles & Keyes, 2002; Cook, 2002; Reason, 1990). For instance, bar coding technology can prevent patient misidentifications, but the possibility exists that an error during patient registration may be disseminated throughout the information system and may be more difficult to detect and correct than with conventional systems (Wald & Shojania, 2001).

In summary, we recommend that healthcare decision-makers consider technology as only one piece of a larger puzzle, i.e. the work system. Technology is not always THE solution to patient safety, and may actually create new opportunities for error and patient safety problems. The benefits one may believe to obtain with new technologies may not occur if the technology is not designed appropriately (i.e. according to human factors and ergonomic principles), does not fit with the rest of the work system, or is not implemented with adequate process principles.

5.2 Expertise required

Like any organizational change project, a work (re)design process relies on technical and managerial expertise. The technical expertise relates to work design itself: knowledge about theories and models of work design, and knowledge and experience with tools and methods for analyzing, evaluating and improving work. In the context of health care and patient safety, another area of technical expertise relates to clinical knowledge. The managerial expertise includes project management and leadership (Kovner et al., 1993). It is very likely that all of these various domains of expertise will be spread across a number of people involved in the work (re)design process.

Should every healthcare organization hire an expert in work design? The answer is probably not, but many should. Whereas some of the principles and methods of work design are relatively intuitive ('common sense') and easy to apply, work (re)design relies on a very large body of knowledge. For instance, healthcare has largely adopted the techniques of FMEA and RCA (Joint Commission Resources, 2002). There is the danger of illusion: "We are doing RCA's on all of our significant events: that means we practice good human factors and ergonomics". Work design is more than just practicing an FMEA or an RCA or just another set of techniques (Gosbee, 2002). Tables 2 to 4 list the various domains, models and theories of ergonomics, job stress and job/organizational design that relate to work design. Designing or redesigning work relies on a very large body of knowledge that is not easily integrated and applied. There are numerous different elements that one needs to examine when designing work (see section 2.2 for a description of the work system). These elements interact with each other. So, fixing one element does not guarantee good performance and safety if other elements of the work system are not taken into account in the redesign. It takes training, knowledge, skills and expertise to be able to understand and anticipate the many different facets of work.

Gosbee (2002) argues that '[Human Factors Engineering] must become a core competency of anyone who has significant involvement in patient safety activities.' (p.354). There is actually some debate in the field of human factors and ergonomiscs regarding the role of the ergonomists. Drury (1995) argues that 'there is no substitute for the ergonomist's knowledge and understanding of both the system under study and the ergonomics literature' (p.66-67). Corlett (1991) states that '[We must] give ergonomics away, … transfer our knowledge and methods to others who are closer to the places where changes have to be made, so that they do much of the ergonomics for themselves. … Until ergonomics is widely practiced by other than professional ergonomists, it is likely to remain something to be added on at the end.' (p.418). In this report, we have presented methods and principles that are easily taught by non-specialists. For instance, in section 3.8.3, we describe two postural analysis methods, RULA and OWAS, that are relatively simple to use. Other methods, models and principles, such as simulation games and participatory ergonomics, aim at transferring knowledge to the 'end-users' and making them an integral part of the redesign process. These contribute to 'giving ergonomics away' as Corlett (1991) recommends. However, other methods, models and theories of work design require a high level of technical expertise and cannot be easily and quickly 'given away'.

In addition, ‘experts’ and ‘end-users’ may have different roles at different stages of the work design project (Haims & Carayon, 1998b; Karltun & Eklund, 2000). The participatory ergonomics model of Haims and Carayon described in section 3.8.5 shows that, at the beginning of the process, the ergonomists had a lot of say and decision-making power. Over time, when the participatory process unfolded, end-users gained knowledge, skills and control via feedback and learning, and had a much more important role.

The dissemination of work design knowledge and skills needs to be achieved through various mechanisms, from trial-and-error (and ‘getting started’, see next section 5.3) to in-house expertise, the use of consultants and various education and training mechanisms. There should be some significant effort to increase the knowledge of the ‘end-users’, i.e. the nurses whose work is redesigned. This can take place via curriculum redesign or various forms of continuous education (e.g., on-the-job coaching, continuing education program).

In conclusion, the field of work design requires knowledge and skills in various domains. Therefore, a multi-faceted approach is required in order to disseminate models and practice of good work (re)design. This approach should rely on the following elements:

- Need to know when to call an expert. The involvement of work design expertise is probably critical at the beginning of the work design journey. It is important to recognize that some aspects of work design are relatively intuitive, but that many design criteria and methods are not all ‘common sense’.
- Opportunity to learn. Any work design project with in-house or consulting technical expertise should be an opportunity to learn.
- Training and education of nurses.

5.3 Get started…

The publication in 2001 of a report on patient safety practices (Shojania, Duncan, McDonald, & Wachter, 2001) has generated much discussion among experts. A series of two articles published in the Journal of the American Medical Association in 2002 displays some of the ‘tension’ generated by the publication of this report in the field of patient safety and quality of care (Leape, Berwick, & Bates, 2002; Shojania, Duncan, McDonald, & Wachter, 2002). We find one of the arguments interesting to mention in the context of work (re)design and patient safety, i.e. ‘get started, don’t wait for all the evidence to improve work’.

In this report, we have presented a large body of knowledge on work design, including the fields of ergonomics (or human factors), job stress and job/organizational design. We have also described some of the methods that have been developed to evaluate and improve work design. Whereas some of these methods have been largely adopted by healthcare institutions and organizations, many of them have not. Some of the work design principles and criteria widely tested and accepted in industries have not been implemented in healthcare. Leape, Berwick and Bates (2002) mention the issue of work hours as an example. A lot is known about the negative impact of long working hours or poorly designed shiftwork systems on performance and well-being (see, for example, Monk & Tepas, 1985), however, there is still on-going discussion in healthcare about whether/how/why to redesign scheduling, including working hours and shiftwork.

As demonstrated in this report, work design involves many different facets of work, both physical elements (e.g., medical equipment design, workspace, workstation and physical environment) and psychosocial elements (e.g., job content, workload, autonomy and participation). Designing or redesigning work cannot be considered as 'the program du jour'. It should be an on-going journey, a continuous improvement process, a learning opportunity, etc… Selected work design criteria or principles and selected work design methods are now largely adopted, or at least recognized, in healthcare. However, work (re)design is more than just limiting noise and conducting an FMEA or an RCA. Work design is multi-faceted and should be conceived and conducted as a continuous improvement process. Work design may also become embedded in many of the functions and activities of a healthcare organization, such as engineering management, quality improvement, quality assurance, occupational safety and health, and human resource management.

Work (re)design certainly represents a long journey, but, if not already done, healthcare organizations should get started. There is much knowledge available in the work design literature and in other industries that can be applied to healthcare. With regard to patient safety practices, Leape, Berwick and Leape (2002) state that 'For policymakers to wait for incontrovertible proof of effectiveness before recommending a practice would be a prescription for inaction and an abdication of responsibility' (p.507). The same comment applies to work (re)design.

This report covers many different facets of work design: conceptual and theoretical foundations (section 2) and work design process and methods (section 3). Given this wealth of work design criteria and methods, how should one get started? The most important issue in work design is to understand the many different aspects of work. Work design is not just conducting an FMEA, is not just reducing noise, is not just adapting the workspace… Work has many different elements: the *individual* performing various *tasks* using *tools and technologies* within a *physical environment* under *organizational conditions*. The work system model of the Balance Theory of job design is probably where anyone should begin in the work design journey. One approach is for every healthcare organization and nurse to start answering the questions on the work system (see Box 2 in section 2.2.). By answering these questions, one can start having an understanding of the many different elements of work design. This is the first step on the road to improving work and patient safety.

### 5.4 Participation

Participation of nurses in the design or redesign of their work systems is critical. Participation is a key criterion in 'good' positive work design. For instance, the Job Characteristics Theory (Hackman & Oldham, 1976) and the Job Enrichment theory (Herzberg, 1974) suggest that increased autonomy and responsibility are key characteristics of a good work design. Employee participation can provide the nurses opportunity to be more autonomous and responsible. Other job/organizational design theories have also highlighted the importance of employee participation as a key motivator and contributor to high-quality performance (Lawler III, 1986; Trist, 1981). Besides being a key work design criterion, participation is also an important characteristic of any change process. In section 3.8.5, participatory ergonomics is described as a powerful method for implementing physical work redesigns. Therefore, participation is important in itself, but also as a method for facilitating the design or redesign of nursing work.

Participation can take different forms and levels (Cotton, Vollrath, Froggatt, Lengnick-Hall, & Jennings, 1988; Wilson & Haines, 1997). Section 3.8.5, for instance, offers a description of the different dimensions of participatory ergonomics. Participation of nurses can involve decision-making regarding a range of issues, such as purchasing of equipment, design of patient's room, implementation of patient care policies and procedures, and work schedules.

Full, direct participation in every aspect of the work design may not be feasible for all nurses affected by the work redesign project. Participatory activities take time away from patient care, and this may be difficult to achieve in certain high-stress, time-pressure environments such as intensive care units. A study of participatory ergonomics teams in three hospital units, including an ICU, provides some evidence of the difficulty for ICU nurses to take time away from patient care in order to participate in a work redesign effort (Bohr et al., 1997). Therefore, we may need to be innovative in identifying ways of involving nurses in a work design effort. At the minimum, we recommend that input should be sought after from nurses whose work is being (re)designed. The method for gathering this input should be designed in such a way as to minimize interruptions. However, an initial time investment may be necessary in order to get started on the work design journey. That initial investment may require additional work for the participants. However, it is important to understand that the work redesign itself can be a way of reducing workload or balancing workload. For instance, identifying performance obstacles due to the various elements of the work system may lead to reduction of 'unnecessary' sources of workload.

Participation of nurses in work design can take different forms at different times in a work design effort. Participation in itself can be rewarding (e.g., learning new skills), and is also important in shaping the work design solutions and their implementation. Implementing participatory processes that do not put undue workload on the participants is critical.

## 6. Conclusion

This report has examined the field of work design and its application to nursing work and patient safety. We have highlighted the many different facets and elements of work design. Work design can impact patient safety via many different pathways and mechanisms:

- Work redesign may directly target the causes or sources of patient safety problems.
- Work redesign may lead to improved efficiencies by removing performance obstacles, therefore freeing up time and reducing workload for nurses to provide better, safer patient care.
- Work redesign may lead to the re-examination of who does what, i.e. the objectives of work, and indirectly improve quality and safety of care.
- Work design can improve care processes, and therefore patient outcomes, including patient safety.

The field of work design relies on three major areas: ergonomics (or human factors), job stress and job/organizational design (see Tables 2-4). Many of these areas have been described in this report. For more information, the interested reader is encouraged to explore the bibliography presented in Appendix A. The third section of the report describes various methods that one can use to design or redesign nursing work. Some of these methods are largely used in health care, whereas others are not. We would like to encourage healthcare institutions to look into some of the work design methods and models that have not yet been adopted and adapted.

The report concludes with a series of recommendations. The recommendations are aimed at healthcare decision-makers at all levels, from the 'microsystem' level to the organizational level and all the way to the general healthcare environment (Berwick, 2002). The recommendations can be directly applied at the 'microsystem' or the organizational levels. However, they also have broader implications for other healthcare decision-makers. For instance, given the complexity and size of the work design field, much education and training is required. This may affect not only the healthcare organizations engaged in a work design project, but also the nursing schools and other educational institutions that train the nurses whose work is (re)designed and the participants and stakeholders involved in the work (re)design process.

One of the key recommendations of this report is to 'get started', preferably by starting to understand that work has multiple elements. Answering the questions in Box 2 is one approach to understand the work system model.

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Figure 1 – Work System Model (Carayon & Smith, 2000; Smith & Carayon-Sainfort, 1989)

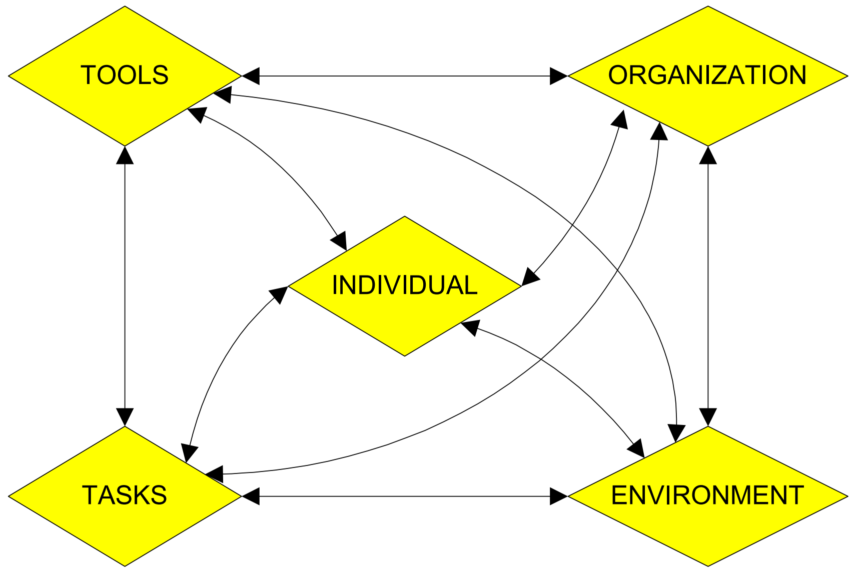

Figure 2 – Ergonomics Design Process (Wilson, 1995b)

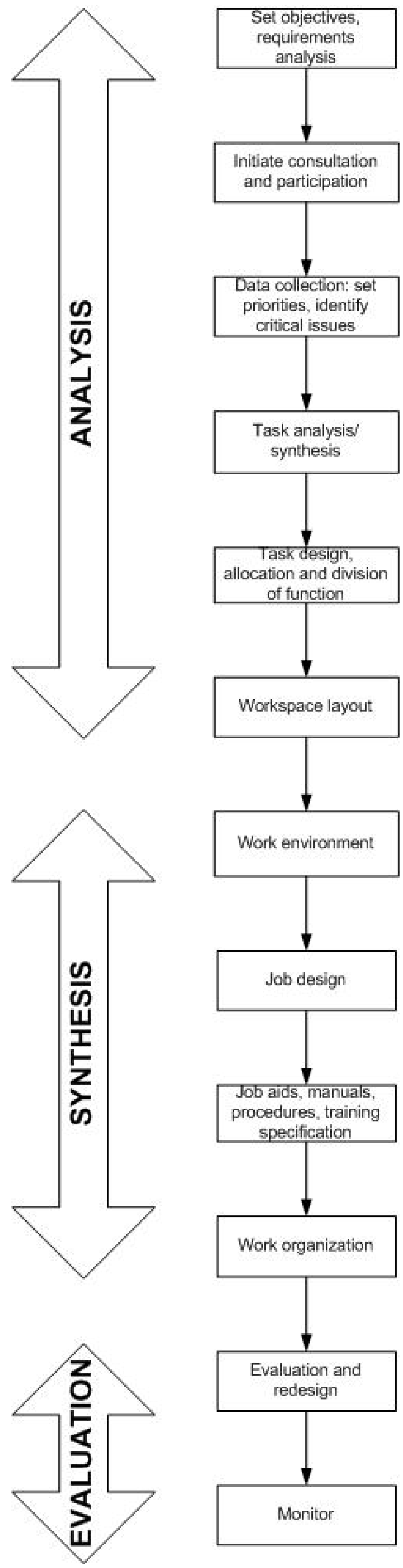

Figure 3 – Structured Work Redesign (Parker & Wall, 1998)

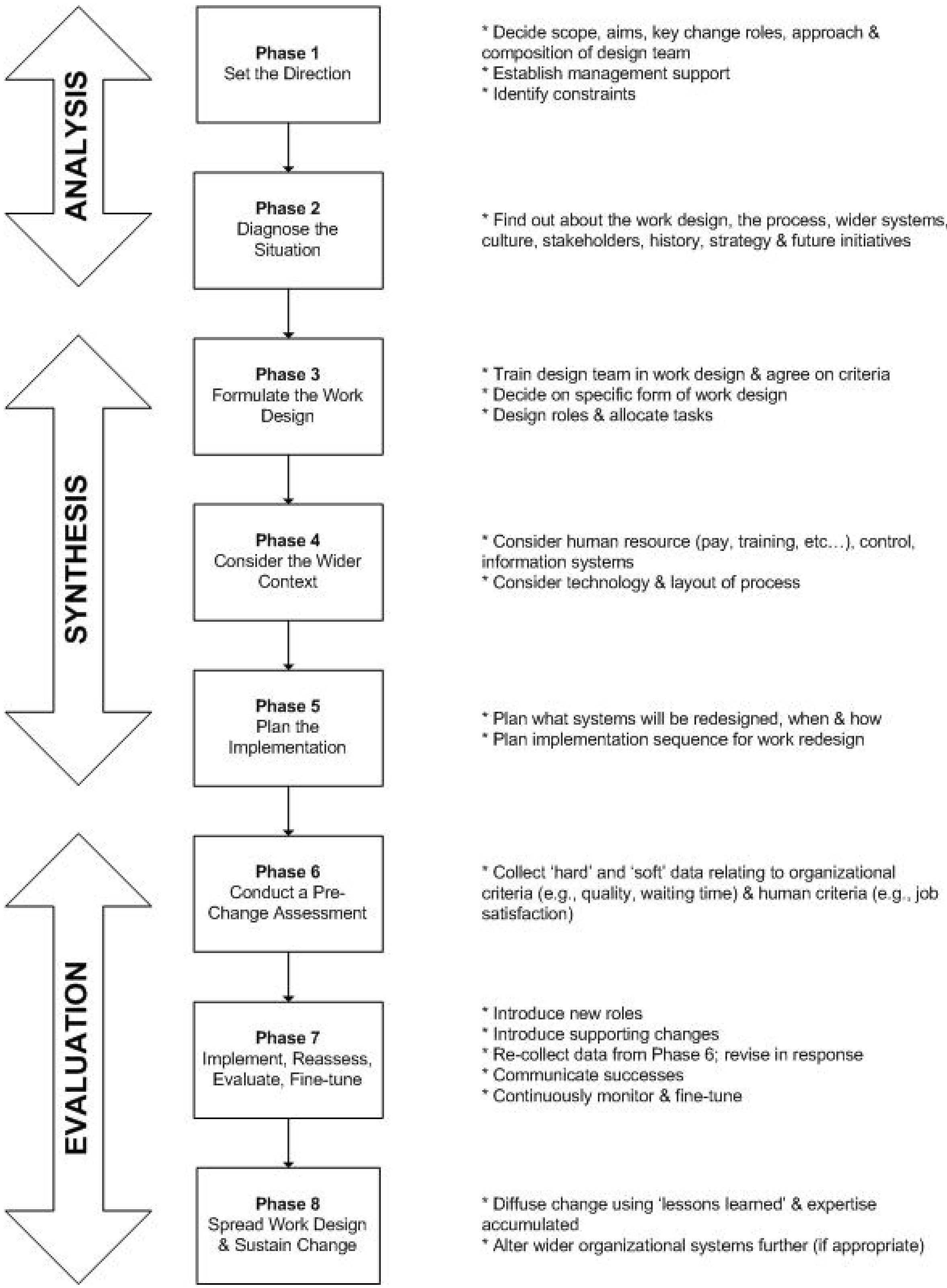

Table 1 – Levels of Factors Contributing to Human Error

| AUTHORS AND APPROACHES | LEVELS OF FACTORS CONTRIBUTING TO HUMAN ERROR |
|---|---|
| Rasmussen (2000): levels of a complex socio-technical system | Work<br>Staff<br>Management<br>Company<br>Regulators/associations<br>Government |
| Moray (1994): hierarchical systems approach that includes several layers | Physical device<br>Physical ergonomics<br>Individual behavior<br>Team and group behavior<br>Organizational and management behavior<br>Legal and regulatory rules<br>Societal and cultural pressures |
| Johnson (2002): four levels of causal factors that can contribute to human error in healthcare | Level 1 factors that influence the behavior of individual clinicians (e.g., poor equipment design, poor ergonomics, technical complexity, multiple competing tasks)<br>Level 2 factors that affect team-based performance (e.g., problems of coordination and communication, acceptance of inappropriate norms, operation of different procedures for the same tasks)<br>Level 3 factors that relate to the management of healthcare applications (e.g., poor safety culture, inadequate resource allocation, inadequate staffing, inadequate risk assessment and clinical audit)<br>Level 4 factors that involve regulatory and government organizations (e.g., lack of national structures to support clinical information exchange and risk management). |
| For comparison, levels of factors contribution to quality and safety of patient care | |
| (Berwick, 2002; Institute of Medicine Committee on Quality of Health Care in America, 2001) | Level A – experience of patients and communities<br>Level B – microsystems of care, i.e. the small units of work that actually give the care that the patient experiences<br>Level C – health care organizations<br>Level D – health care environment |

Table 2 – Ergonomics in the Work System

| FIELDS IN ERGONOMICS | WORK SYSTEM ELEMENTS | | | | | |
|---|---|---|---|---|---|---|
| | Individual | Tasks | Tools & technologies | Physical environment | Organizational conditions | For more information… |
| Environmental design | | | | Workspace design<br>Noise<br>Vibration<br>Lighting<br>Climate | | (Konz, 1983; Salvendy, 1997) |
| Tool design | | | Medical device design | | | (Sanders & McCormick, 1993) |
| Workspace and workstation design | | | Workstation design | Workspace design | | (Kroemer et al., 2001; Sanders & McCormick, 1993) |
| Work schedules | | | | | Shiftwork system design | (Monk & Tepas, 1985) |
| Human-computer interaction | | Usability | Interface design | | | (Jacko & Sears, 2003) |

Table 3 – Job Stress in the Work System

| MODELS & THEORIES OF JOB STRESS | WORK SYSTEM ELEMENTS | | | | | |
|---|---|---|---|---|---|---|
| | Individual | Tasks | Tools & technologies | Physical environment | Organizational conditions | For more information… |
| Karasek's Job Strain model | | Workload<br>Job decision latitude | | | Social support | (Karasek & Theorell, 1990) |
| Cooper and Marshall's model | | Work overload & time pressure | | Poor working conditions | Role ambiguity & conflict<br>Responsibility<br>Lack of job security<br>Little or no participation<br>Poor organizational climate | (Cooper & Marshall, 1976) |
| Role stress | | | | | Role ambiguity<br>Role conflict<br>Role overload | (Kahn, 1981) |
| Person-Environment Fit Theory | Misfit between the Person's *needs*…<br><br>Misfit between the Person's *abilities*… | …and the Work Environment's *supplies*, e.g., boredom<br><br>…and the Work Environment's *demands*, e.g., overload | | | | (Caplan, Cobb, French, Harrison, & Pinneau, 1975; Edwards, 1988) |

Table 4 – Job/Organizational Design in the Work System

| MODELS & THEORIES OF JOB/ ORGANIZATIONAL DESIGN | WORK SYSTEM ELEMENTS | | | | | |
|---|---|---|---|---|---|---|
| | Individual | Tasks | Tools & technologies | Physical environment | Organizational conditions | For more information… |
| Scientific Management | | Simple, repetitive tasks | Adequate tools for the tasks | | | (Taylor, 1911) |
| Job rotation | | Regular rotation between tasks | | | | (Parker & Wall, 1998) |
| Job enlargement | | Increasing the number of tasks | | | | (Parker & Wall, 1998) |
| Job enrichment | | Upgrading tasks to include extra 'skilled tasks' | | | Increased employee responsibility, such as making decisions about work scheduling and task allocation | (Herzberg, 1974) |
| Job Characteristics Theory | | Skill variety<br>Task completeness<br>Task significance<br>Autonomy<br>Feedback | | | | (Hackman & Oldham, 1976) |
| Sociotechnical Systems Theory | Options to accommodate individual differences and circumstances | Challenge<br>Ability to learn<br>Scope of decision-making | | | Social support<br>Recognition<br>Job future<br>(Semi-)autonomous work groups | (Davis & Wacker, 1987; Emery & Trist, 1965; Trist, 1981) |
| Teamwork | Group design-composition<br>Knowledge and skills | Group design-structure of task<br>Level of effort | | | Organizational context (reward, education, information)<br>Group synergy | (Hackman, 1987, 1989; Tannenbaum et al., 1996) |

| | | | | | | |
|---|---|---|---|---|---|---|
| High Involvement Management | | | | | Power<br>Knowledge<br>Information<br>Rewards | (Lawler III, 1986) |
| Organizational climate and culture | | | | | Organizational climate and culture<br>Safety climate and culture | (Helmreich & Merritt, 1998; Hofstede, 1997) |

TABLE 5 – Ergonomic Design Principles

| Design principles | Solutions | Examples of application in nursing work |
|---|---|---|
| Minimize perception time | Visible parts: nothing hidden<br>Visual discrimination, using appropriate size and color<br>Tactile discrimination, using appropriate texture and size | Larger display fonts on patient monitors and medical devices that can be read from across the room<br>Cardiac monitors using red display for heart rate<br>Red alarm knobs<br>Sand-paper finishes on door knobs designating no entrance |
| Minimize decision time | Ease the formation of a mental model: visible parts, minimize number of parts<br>Reduce choice reaction time: collocation of associated items<br>Spatial compatibility<br>Visual, auditory and tactile feedback | Different alarm sounds associated with various medical devices, i.e. distinct chimes of an IV pump alarm rather than a buzz or a beeping alarm on a respirator<br>Code button and pocket resuscitation device at the end of the patient's bed that can be quickly accessed for CPR<br>Patient headboards with blood pressure cuffs and suction devices on both sides of the bed<br>Electronic 'sticky' buttons on devices and electronic sounds giving a traditional mechanical 'switch' or 'button' feel and sound to use |
| Minimize manipulation time | Ease of manipulation<br>Physical affordances and constraints<br>Design for transfer of training: e.g., new product or equipment similar to old | In-line suction catheters eliminating the need for two persons during respiratory suction<br>Computer simulation and training on new devices prior to use on the patient floor<br>Patient beds showing the degree of elevation showing the degree of elevation on the bedside by the patient's bed |
| Optimize opportunity for movement | Ease of access of equipment and materials<br>Location of equipment and materials | Balance between need to move for patient care duties and need to stand for recording or for standing at the nursing station |
| Minimize need for human strength | Use of mechanical devices<br>Eliminating need for human strength | Patient beds with built-in weight scales<br>Beds that rotate from side to side<br>Beds with alarms when patients attempt to leave the bed<br>Patient gurneys that allow for X-ray or fluoroscopy eliminating the need for transfer to an X-ray table |

Appendix A – Bibliography on Work Design

| For more information on … | See … |
|---|---|
| General human factors and ergonomics | Salvendy, G. (Ed.). (1997). *Handbook of Human Factors and Ergonomics* (Second edition ed.). New York, NY: John Wiley & Sons.<br>Sanders, M. S., & McCormick, E. J. (1993). *Human Factors in Engineering and Design*. New York, NY: McGraw-Hill. |
| Human factors evaluation | Wilson, J. R., & Corlett, E. N. (Eds.). (1995). *Evaluation of Human Work - A Practical Ergonomics Methodology* (Second Edition). London: Taylor & Francis. |
| Job stress | Kalimo, R., Lindstrom, K., & Smith, M. J. (1997). Psychosocial approach in occupational health. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics* (pp. 1059-1084). New York: John Wiley & Sons.<br>Quick, J. C., Quick, J. D., Nelson, D. L., & Hurrell, J. J. J. (1997). *Preventive Stress Management in Organizations* (Second ed.). Washington, DC: American Psychological Association. |
| Job/organizational design | Parker, S., & Wall, T. (1998). *Job and Work Design*. Thousand Oaks, CA: Sage Publications.<br>Lawler III, E. E. (1986). *High Involvement Management:  Participative Strategies for Improving Organizational Performance*. San Francisco: Jossey-Bass. |

Appendix B – Job Analysis Form (© Pascale Carayon and Michael J. Smith, University of Wisconsin-Madison Department of Industrial Engineering; Job Analysis Form – Revised: January 10, 2003)

# JOB ANALYSIS

Organization

---

Department

---

Job title

---

Who performed the job analysis?

---

When was the job analysis performed?

---

| How was data collected? For how long? Using what data collection procedure and forms? |
|---|
| |

**Individual**

| |
|---|
| Individual characteristics related to the job (skills, knowledge, education, training, work experience) |

## Tasks

| Tasks performed (content, timing, flow) |
| --- |
| |

| Methods and procedures used to perform tasks |
| --- |
| |

| Responsibilities |
| --- |
| |

| Supervision received |
| --- |
| |

| Supervision given |
| --- |
| |

**Tools and technologies**

| Devices, machines and equipment used |
| --- |
| |

| Information and communication technologies (e.g., computers, bar coding) |
| --- |
| |

| Workstation ergonomics (e.g., dimension, postures, etc…) |
| --- |
| |

## Physical environment

Workspace, layout and location

Illumination:
- ❑ poor
- ❑ adequate
- ❑ good
- ❑ excessive

Extreme cold with or without temperature changes ☐

Extreme heat with or without temperature changes ☐

Wet and/or humid ☐

Noise
- ❑ minimal
- ❑ noticeably loud
- ❑ very loud

Vibration (hand-tools)
- ❑ little
- ❑ noticeable
- ❑ great deal

Safety hazards
- ❑ mechanical
- ❑ electrical
- ❑ burns
- ❑ explosives
- ❑ other: _____________________________________________

Atmospheric conditions:
- ❑ fumes
- ❑ odors
- ❑ dust
- ❑ mist
- ❑ gases
- ❑ poor ventilation
- ❑ other: _____________________________________________

## Organizational conditions

| Helper or assistance |
|---|
| |

| Co-workers |
|---|
| |

| Team work |
|---|
| |

| Coordination with other jobs and departments |
|---|
| |

| Patient contact |
|---|
| |

| Socialization |
|---|
| |

| Standards for performance (quota; quantity and quality) and performance evaluation process |
| --- |
| |

| Hours of work |
| --- |
| |

| Pay system and benefits |
| --- |
| |

| Permanency |
| --- |
| |

| Promotion / advancement |
| --- |
| |

| Training |
| --- |
| |

## Appendix C - Simulation Game - The Softmatch Method (Smeds, 1997)

| | | |
|---|---|---|
| | Starting the development project | |
| **1** | Choose the target process, set the objective, organize the change project, inform<br>Duration: ½ day | Top management of the company unit, change project team |
| | First simulation game | |
| **2** | a. Prepare the simulation<br>Duration: 1 day | Change project team and employees knowing the different process phases<br>4-6 persons |
| | b. Inform the simulation game participants<br>Duration: 1-2 hours | Simulation game team<br>15-50 persons |
| | c. Arrange the simulation game room<br>Duration: ½ day | Change project team<br>2-3 persons |
| | d. Play the simulation game<br>Duration: 2 ½ days | Simulation game team: sufficient representation from all process activities, plus observers<br>15-50 persons |
| | Development of the new process | |
| **3** | a. Prepare the development phase<br>Duration: ½-1 day | Change project team<br>4-6 persons |
| | b. Design and model the new process, establish sub-projects<br>Duration: 1-2 days | Process development team, typically 1/3 of the simulation game team |
| | c. Run the subprojects to build up the preconditions for the new process<br>Lead-time: ½-2 months | Subproject teams<br>2-5 persons in each team |
| | d. Screen the results of the subprojects<br>Duration: ½-1 day | Process development team, typically 1/3 of the simulation game team |
| | Second simulation game | |
| **4** | a. Prepare the simulation<br>Duration: 1 day | Change project team<br>4-6 persons |
| | b. Inform the simulation game participants<br>Duration:1-2 hours | Simulation game team<br>15-50 persons |
| | c. Arrange the simulation game room<br>Duration: ½ day | Change project team<br>2-3 persons |
| | d. Play the simulation game | Simulation game team, sufficient representation from all process activities, plus observers<br>15-50 persons |
| | Piloting the new process | |
| **5** | Piloting the new process, ensuring its preconditions | The responsible organization and the implementation team |
| | Implementation and follow-up | |
| **6** | Full-scale implementation and follow-up of the new process | The responsible organization and the implementation team |

SHORT BIOSKETCHES

Pascale Carayon, Ph.D., is a Professor of Industrial Engineering at the University of Wisconsin-Madison and the Director of the Center for Quality and Productivity Improvement. She received her Engineer diploma from the Ecole Centrale de Paris, France, in 1984 and her Ph.D. in Industrial Engineering from the University of Wisconsin-Madison in 1988. Her research areas include systems engineering, human factors and ergonomics, sociotechnical engineering and occupational health and safety in a variety of industries, including health care. She is a member of the editorial board of the following journals: *The International Journal of Human-Computer Interaction, Work and Stress* and *Behaviour and Information Technology*. She is a scientific editor for *Applied Ergonomics*. She is the chair of the technical committee on Organizational Design And Management of the International Ergonomics Association (IEA), and is a member of the executive committee of the IEA, in charge of the *Ergonomics In Quality Design* (EQUID) program.
Her current research projects include:

- systems engineering and human factors engineering in healthcare (funded by the Agency for Healthcare Research and Quality)
- medication error reduction, technologies and human factors (funded by the Agency for Healthcare Research and Quality)
- human factors and organizational issues of critical infrastructure protection (funded by the Department of Defense)
- quality of working life in a diverse IT workforce (funded by the National Science Foundation)
- relationship between job characteristics and occupational health (founded by the National Institute on Aging and the National Institute for Occupational Safety and Health)

Carla J. Alvarado, Ph.D., is a Research Scientist at the Center for Quality and Productivity Improvement, University of Wisconsin-Madison. She received her B.S. from Miami University, Oxford, Ohio; her M.S. in Preventive Medicine-Epidemiology in 1988 and her Ph.D. in Industrial Engineering-Human Factors in 2003 from the University of Wisconsin, Madison, WI. Prior to her present position, she was employed as an Infection Control Professional for 19 years at the University of Wisconsin Hospitals and Clinics, Madison, WI. Her publications and research areas include nosocomial infections associated with medical devices, safety culture/safety climate, and human factors and ergonomics related health care.She is a co-author of a national guideline on the prevention of infections related to flexible endoscopy. She is a member of the editorial board of *The American Journal of Infection Control*. She has served on the national board of directors of the Association for Professionals in Infection Control and Epidemiology (APIC), the American Hospital Association (AHA) Advisory Board on Infections in Hospitals, and the board of trustees of the Research Foundation for Prevention of Complications Associated with Health Care. She is a national and international speaker on infection control and human factors in health care. She is board certified in infection control.
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Ann Schoofs Hundt, Ph.D., is a research scientist at the Center for Quality and Productivity Improvement at the University of Wisconsin Madison. She received her graduate degrees in Industrial Engineering from the University of Wisconsin-Madison. Prior to entering graduate school, she was Director of Medical Records and Quality Assurance at the University of Wisconsin Hospital and Clinics where she worked on numerous nursing-related task forces addressing quality of care issues. Part of her graduate work included working with Dave Gustafson, Ph.D. and the then-National Demonstration Project on Quality Improvement in Health Care (now the Institute for Healthcare Improvement) when she managed a computerized decision support system made available to all members of the NDP. She has also participated on a recent research project evaluating the implementation of an electronic medical record in a small family practice clinic. She currently is working on an AHRQ DCERPS (Development Center for Evaluation and Research in Patient Safety) grant assessing quality of care and patient safety issues in outpatient surgery, and on an AHRQ-funded project on medication error reduction, technologies and human factors.