Ergonomic Investments

A plant-level exploratory analysis

By Tony Brace and Anthony Veltri

THE OCCURRENCE OF MUSCULOSKELETAL disorders (MSDs) in U.S. workplaces can be a significant business concern (Whysall, Haslam & Haslam, 2006; Graves, Way, Riley, et al., 2004; Rodrigues, 2001; GAO, 1997; NIOSH, 1993). MSDs are typically linked to employee operating errors that result in substandard work quality and reduced operational productivity (Graves, et al., 2004; Beevis & Slade, 2003; Beevis, 2003; Van Fleet & Bates, 1995). In 2002, MSDs accounted for 487,900 (34%) of the injuries and illnesses in the U.S. involving days away from work (Whysall, et al., 2006). Between 1994 and 2002, the state of Washington estimated the cost of workers' compensation linked to MSDs to be $3.3 billion (Silverstein, Adams & Kalat, 2005).

This problem is not unique to U.S.-based industries. MSDs are the most common form of work-related illness in today's industrialized nations. In Great Britain, for example, MSD risk factors can be found in virtually every occupation and workplace (Graves, et al., 2004). In 2003, work-related MSDs represented two-thirds of occupational diseases in France, with an incidence rate of more than 1 in 1,000 workers (Roquelaure, Ha, Leclerc, et al., 2006).

Evidenced-based research has shown that confronting and managing MSDs in the workplace improves employee work performance (Beevis & Slade, 2003, Hendrick, 2003; Seeley & Marklin, 2003; Yeow & Sen, 2003; Alexander, 1998; Hendrick, 1996) and overall operational productivity (Freivalds & Yun, 1994). Nevertheless, management and technical specialists (e.g., senior-level executives, operations managers, financial specialists, and design and process engineers) remain skeptical about implementing engineering and administrative controls and practices. Instead, they tend to perceive ergonomic-type investments as an unnecessary expense rather than as a fiscally prudent investment intended to enhance business performance (Wynn, 2003; Hendrick, 2003; Fletcher, 2001; Hendrick, 1996). This skepticism exists in part because ergonomic specialists have not provided a compelling business case to management and technical specialists. The purpose of this plant-level analysis is to take an exploratory step toward simplifying the methodological aspects of making investments in ergonomic practices, while making the economic and operational implications of those investments transparent.

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Background

A recreational vehicle manufacturing plant located in the Pacific Northwest volunteered to participate in the exploratory analysis and agreed to the methods necessary to conduct it. The company has been in business for 38 years and typically employs approximately 6,000 management and line-level workers annually.

Concerned about the risk of musculoskeletal injuries to line-level employees, plant management arranged for a plant walk-through in order to discuss the various manufacturing processes and tasks that may be linked to musculoskeletal risks and disorders. This walk-through was conducted in order to observe the production process and identify specific tasks that could present exposures to musculoskeletal risk factors (e.g., forceful exertions, awkward postures, static loading, vibration) independent of the presence of historical injuries. Plant management wanted to avoid limiting the scope of the inspection to only tasks associated with injuries, believing this could cause those involved to overlook areas that may contribute to risks despite not being associated with an injury.

Plant management identified three manufacturing processes for consideration during the walk-through: wall press, wall production and end cap. This selection was based on employee reports of discomfort during production work. The wall-production process was selected for the analysis because musculoskeletal risk factors (forceful exertions, awkward postures, vibration) were observed during the cut and sand (C&S) task of this process.

The Cut & Sand Task

The C&S task is initiated when wall panels are delivered from the lamination area. The panels are made up of 10 component plywood sheets with a finished fiberglass side and an unfinished plywood side that are bonded together to make the panel 8 ft wide x 44 ft long. Panels are lifted by an overhead crane from a staging table and are tilted into a vertical position so the fiberglass seams can undergo a quality inspection. Once the inspection is complete, the panel is tilted back to a horizontal position and placed, plywood side up, on a C&S preparation table. The overhead crane is then released and moved back to its starting position.

The C&S task involves two key activities: 1) sand the seams on the plywood to remove imperfections (Photo 1); and 2) cut excess material off the panel's perimeter so it is uniform in dimension (Photo 2). To perform these activities, all four edges of the panel must be measured and marked with chalk to determine where the panels are to be cut. Once the cut line has been determined, an employee uses a saw to cut the panel's side edges.

After one edge and one side have been cut, a second employee begins to sand the panel's plywood side seams. When all sides and ends are cut, both employees finish the sanding process. Ten seams require sanding, one half of a seam at a time. Once the panel is cut and sanded, it is picked up by the overhead crane and moved to the next manufacturing process (wall production).

The C&S task involves two key activities: 1) sand the seams on the plywood to remove imperfections (Photo 1, top) and 2) cut excess material off the panel's perimeter so it is uniform in dimension (Photo 2).

Abstract: *This article shares a plant-level analysis of an ergonomics intervention. The outcome is an exploratory protocol for educators, students and field practitioners to consider as they go about making the operational and economic implications of ergonomics investments more transparent.*

Method

The methodology used to conduct the plant-level exploratory analysis occurred in three phases (see sidebar below). Phase 1 involved a walk-through of the plant with management to discuss and examine the various manufacturing processes and tasks that may be linked to musculoskeletal risks and disorders, obtaining plant management support to conduct the analysis and securing Institutional Review Board (IRB) approval. In addition, operating performance information and data about the C&S task were provided (e.g., number of hours worked/-day, employee fully loaded labor rate, number of panels manufactured/day, process history, concern for possible exposures to musculoskeletal risks and disorders).

Phase 2 involved videotaping three full work cycles of the C&S task in order to record and later study the various operating tasks and subtasks involved and to determine the level of musculoskeletal risk and estimate operational impact. Informed consent was obtained from the plant manager and from the participating line-level employees to videotape the task.

A functional task analysis (Table 1, p. 26) was conducted (Gramopadhye & Thaker, 1998; Luczak, 1997; Champanis, 1996; Chengalur, Rodgers & Bernard, 2004) to identify and isolate musculoskeletal risk factors as well as to calculate the operational impact, specifically the existing level of task efficiency. The videotape was used and conventional ergonomic analysis assessment tools such as the rapid upper limb assessment (RULA) (Chengalur, et al.), American Conference of Governmental Industrial Hygienists (ACGIH) hand activity level (HAL) threshold limit value (TLV) (Chengalur, et al.) and Moore Garg Strain Index (SI) (Karwowski & Marras, 1998; Moore & Garg, 1995) were employed.

To estimate operational impact, the study team used a predetermined time standard technique called Maynard Ope-

Exploratory Analysis Methodology

Unit & Level of Analysis = Individual Plant Site

Phase 1: Perform Up-Front Analysis

- Conduct plant walkthrough *(examination of manufacturing processes).*
- Obtain plant level management support.
- Secure institutional review board approval.
- Obtain operating performance data.
- Videotape task.

Phase 2: Determine Existing Process Risk & Operational Impact (Task Efficiency)

- Assess existing level of musculoskeletal risk.
  - *Functional task analysis*
  - *Conventional ergonomic analysis tools*
    - Rapid Upper Limb Assessment (RULA)
    - ACGIH Hand Activity Level (HAL)
    - Moore/Garg Strain Index
- Assess existing operational impact *(task efficiency).*
  - *Engineering work measurement tool*
    - BasicMOST

Phase 3: Estimate Proposed Solution Risk & Operational Impact (Task Efficiency)

- Estimate proposed solution level of musculoskeletal risk.
  - *Functional task analysis*
  - *Conventional ergonomic analysis tools*
    - RULA
    - HAL
    - Moore/Garg Strain Index
- Estimate proposed solution operational impact *(task efficiency).*
  - *Engineering work measurement tool*
    - BasicMOST

Table 1

Existing Functional Task Analysis of Operating Tasks

Task	Task	Subtask	Labor time (TMU)	Labor time (minutes)
1. Move panel to workstation	1.1	1.1.1 Prepare panel for seam inspection	11800	**7.08**
		1.1.2 Inspect seams	2800	**1.68**
		1.1.3 Place panel on cut table	12400	**7.44**
2. Cut panel	2.1 Measure chalk line	2.1.1 Measure and mark first corner	840	**0.504**
		2.1.2 Measure and mark second corner	710	**0.426**
		2.1.3 Measure and mark third corner	820	**0.492**
		2.1.4 Measure and mark fourth corner	660	**0.396**
	2.2 Snap chalk line	2.2.1 Snap chalk line 1	1160	**0.696**
		2.2.2 Snap chalk line 2	520	**0.312**
		2.2.3 Snap chalk line 3	2560	**1.53**
		2.2.4 Snap chalk line 4	1160	**0.696**
	2.3 Cut panel	2.3.1 Prepare cutting equipment	960	**0.576**
		2.3.2 Cut end of panel	800	**0.48**
		2.3.3 Cut side of panel	4120	**2.472**
		2.3.4 Cut second end of panel	700	**0.42**
		2.3.5 Cut second side of panel	2000	**1.2**
		2.3.6 Remove cutting equipment	420	**0.252**
3. Sand panel	3.1 Preparation for sanding	3.1.1 Prepare for sanding	420	**0.252**
	3.2 Sand seams	3.2.1 Sand 13 half seams	5083	**3.0498**
		3.2.2 Sand 13 half seams (*other side of panel*)	4823	**2.8938**
	3.3 Post sand	3.3.1 Remove sanders	420	**0.252**
Total labor time (minutes)				**33.09**

rating Sequence Technique (BasicMOST) (Konz & Johnson, 2004; Niebel & Freivalds, 2003; Zandin, 2001). Table 1 displays a hierarchical functional task analysis, including labor time estimations from a BasicMOST analysis based on the videotape.

Phase 3 focused on estimating the level of musculoskeletal risk and operational impact of the proposed solution using the same tools employed in phase 2 (Table 2).

Given the exploratory nature of the study, no attempt was made to create or promote a unique technique for conducting an ergonomic analysis or recommend a grand analysis strategy for confronting and managing musculoskeletal risk; rather, the study focused on one demonstration of a valid, factual ergonomic problem with the level of analysis focused at the factory site.

The result is a discussion of the MSDs affecting the plant, a countermeasure strategy for confronting and managing those disorders, and the operational and cost results of implementing the countermeasure strategy compared to taking no action at all. The intention is to leave the task of empirical testing of the assessment technique, methods employed in the case study, selected tools and the proposed solution strategy to future researchers.

However, having built the case study plan and being in a unique position to simplify a single plant's experience of making ergonomic-type investments, the study at least provides an exploratory protocol for educators, students and field practitioners to consider as they go about making the operational and economic implications of ergonomics investments more transparent.

Findings & Discussion

Functional Task Analysis of Operating Tasks

The purpose of functional task analysis is to depict a sequence of system events that are required to meet the system objectives. Functions or actions related to accomplishing the system objective are identified and described iteratively with high, top-level functions progressively subdividing into simpler subfunctions that become increasingly detailed to lower levels.

Functions are described by using two- to three-word verb-noun phrases (e.g., "get part," "prepare for inspection," "cut panel") and are numbered so that their relationship to higher-level functions can be easily traced. These functions can be displayed either in a node tree or tabular format where 0 represents the system objective and first-level functions are identified by 1, 2, 3, etc. Second-level functions are identified by 1.1, 1.2, 2.1, 2.2, etc. Third-level functions and beyond are identified by continued extensions of the numbering system (Champanis, 1996). This process then provides a basic map of the system that enhances the ability to discover deficiencies and redirect task or system redesign.

For the functional task analysis of the C&S task, four basic subtasks were observed at the first level: 1) Inspect panel and move to workstation. 2) Cut panel. 3) Sand panel. 4) Prepare and move panel to next workstation (Table 1). Operational efficiency was calculated by analyzing the tasks' labor time. Labor time was computed using BasicMOST (Zandin, 1990; 2001). Such a technique is used to measure the work content inherent in a task to determine basic labor times for doing basic human activities necessary to perform a job or task. BasicMOST is form of a work measurement system that assesses the logistics and activities dealing with the movement of objects (Zandin, 1990; 2001).

The movement of objects (panels) in the C&S task followed a sequential, logistical pattern of reaching, grasping, moving and positioning of the panels. BasicMOST allows for different types of item complexity (e.g., weight, grip, placement, number of turns of a screwdriver) and various distances (e.g., reach, move) an object may travel. As these

Table 2

Proposed Functional Task Analysis of Operating Tasks

Task	Task	Subtask	Labor time (TMU)	Labor time (minutes)
1. Move panel to workstation	1.1	1.1.1 Prepare panel for seam inspection	11800	**7.08**
		1.1.2 Inspect seams	2800	**1.68**
		1.1.3 Place panel on cut table	12400	**7.44**
2. Cut panel	2.1 Check panel placement	2.1.1 Check one side of panel relative to table	460	**0.276**
		2.1.2 Check second edge of panel relative to table	460	**0.276**
		2.1.3 Make first measure for end and mark	310	**0.186**
		2.1.4 Make second measure for side and mark	410	**0.246**
	2.2 Cut panel	2.2.1 Cut first end	1280	**0.768**
		2.2.2 Cut both sides	4480	**2.688**
		2.2.3 Cut last end	2220	**1.332**
3. Sand panel	3.1 Preparation for sanding	3.1.1 Prepare for sanding	420	**0.252**
	3.2 Sand seams	3.2.1 Sand 13 half seams	5083	**3.0498**
		3.2.2 Sand 13 half seams (*other side of panel*)	4823	**2.8938**
	3.3 Post sand	3.3.1 Remove sanders	420	**0.252**
Total labor time (minutes)				**28.4**

sequences are identified and specifics are clarified, labor time values can be readily determined. Labor times are supplied in an industry standard metric called a time measurement unit (TMU); these times are based on statistical calculations that are the same as those that are used in statistical quality control. When used for task cycle times exceeding 2 minutes, BasicMOST measurements are considered to be 95% accurate (Zandin, 1990).

Labor times were developed based on observing two employees performing the tasks and subtasks outlined in the functional analysis. According to the plant manager, the panels observed in the process were representative of those handled on a typical day. Labor times reflected pure work content at the 100% performance level without including variances for fatigue or personal time as this is not needed for MOST calculations.

Based on the videotape, on-site measurements and the functional analysis, the total labor time for two people to perform the C&S process was approximately 33.9 minutes. This is the actual labor time paid for two employees working individually to complete all subtasks related to C&S. Table 1 displays the results of the functional analysis of operating tasks for C&S. Table 2 displays the proposed differences (should the employer implement the recommendations outlined later) in the number of tasks performed and labor times.

Functional Analysis of Existing C&S Task Exposure to Musculoskeletal Risk

Subtasks where the most extreme loaded postures tended to occur were identified based on the functional task analysis. Extreme loaded postures are defined as the point where the head, arms, wrist and/or torso were the farthest away from the body or in the most extreme flexion, extension, abduction or adduction points. Because the C&S process involved hand/wrist/arm activity and awkward postures, musculoskeletal risks were assessed using the rapid entire body assessment (REBA), ACGIH HAL TLV tool and the SI. These tools are designed to measure the type of musculoskeletal risk observed in operating tasks.

REBA is a tool that works by assigning postural scores for the body (i.e., legs, trunk, neck) and scores for the upper distal extremities (i.e., upper arm, lower arm and wrists), and both right and left hands, as they are observed during a task at the most extreme loaded positions. These postural scores are combined with a frequency score to form a single score that indicates the level of musculoskeletal risk employees have of developing an MSD. Risk is calculated on a scale of 1 to 15. A score of 1 indicates negligible risk, 2 or 3 indicate low risk, 4 to 7 are medium risk, 8 to 10 are high risk, and 11 to 15 are very high risk.

The HAL TLV is a tool that assesses hand activity for both hands, and the level of effort for a typical posture when performing a short-cycle task. Two variables were measured:

1) Hand activity level of repetitiveness and duration of exertion were assessed on a scale of 1 to 10, where 0 is virtually no activity and 10 is the highest imaginable hand activity.

2) Normalized peak force (NPF) was assessed on a scale of 0 to 10. NPF is what a person of average strength would exert in the same posture required by the task. A ratio of HAL and NPF is computed and compared to the TLV and action level (AL). Values above .78 exceed the TLV and values above .56 exceed the AL (Chengalur, et al. [TB1], 2004).

The SI is used to assess a task's upper distal extremity (fingers/hands/wrists) musculoskeletal risk. It evaluates six different risk factors of a task and assigns an index number that indicates the level of severity for a particular risk factor. These risk factors are: intensity of exertion; duration of exertion; efforts per minute; hand/wrist posture; speed of work; and number of hours per day the task is performed. Index numbers for all six risk factors are multiplied to provide a risk level score. Scores of less than 3 are safe, 4 and 5 are moderate risk, 6 and 7 are some risk, and scores greater than 7 are high risk (Chengalur, et al., 2004; Karwowski & Marras, 1998; Moore & Garg, 1995).

Based on the results of the hierarchical functional task analysis, of the two subtasks observed, extreme postures appeared to be most prevalent in the cut panel sequence. To perform subtask 1 (Photo 1, p. 25),

Management skepticism about ergonomic investments exists in part because ergonomic specialists have not provided a compelling business case.

Table 3

Analysis of Existing Exposure to Musculoskeletal Risk Factors

Existing C&S task versus proposed solution.

TASK	REBA SCORE Original		REBA SCORE Proposed	
	Left hand	Right hand	Left hand	Right hand
Sanding	9	9	9	9
Cutting	10	7	2	2
Recommended limits:	0 to 3 = No risk to low risk			

TASK	HAL SCORE Original		HAL SCORE Proposed	
	Left hand	Right hand	Left hand	Right hand
Sanding	2.0	2.0	2.0	2.0
Cutting	1.0	0.4	0.25	0.25
Recommended limits:	TLV = 0.78	AL = 0.56		

TASK	SI SCORE Original		SI SCORE Proposed	
	Left hand	Right hand	Left hand	Right hand
Sanding	6.0	6.0	6.0	6.0
Cutting	6.0	6.0	2.25	2.25
Recommended limits:	< 3 = Safe			

an employee holds a power saw in a sustained awkward posture for approximately 5 minutes while holding the weight of the saw, applying force and guidance from the wrist in a static posture. To perform subtask 2 (Photo 2, p. 25), the sanding sequence, each employee holds a sander in a sustained awkward posture for approximately 6 minutes. Table 3 shows the results of the existing versus solution REBA, HAL and SI for both the right hand and left hand. Results showed that for both the sanding and cutting tasks, the postural loading and exertion levels for the upper torso placed employees in a higher musculoskeletal risk category.

Functional Analysis of Proposed C&S Task Exposure to Musculoskeletal Risk Factors

Once all musculoskeletal risks were identified and task labor times were calculated, one recommendation—development of a saw cart—was formulated and discussed with the plant manager. The thinking behind this recommendation was that a saw cart would automatically make the panel cuts—rather than having an employee make the cuts with a saw. This would isolate employees from the identified musculoskeletal risk factors.

The saw cart (Photos 3 and 4) would be positioned on a track that moved over the cutting table. It would have two saws mounted on either side to cut panel sides and one transverse-mounted saw to cut the ends of the panels. Once a panel was laid on the cutting table, the transverse saw would cut one end of the panel; the two side saws would then be aligned to the panel, activated, and the cart would then be pushed down the track simultaneously cutting both sides of the panel. Once the cart reached the other end, the transverse saw would cut the final end of the panel. The panel would then be sanded and moved on to the next step in the manufacturing process.

Musculoskeletal risks and labor time were estimated for the saw cart. The estimated labor time was compared to the current labor time (see Tables 2 and 4) when employees manually cut panel sides with a handheld saw to show an estimated impact to labor productivity and cycle time. This productivity estimation was provided to the employer along with the recommendations. Once the employer implemented the recommended action, the task was reassessed and musculoskeletal risks and labor times were reevaluated using the same methods described earlier to validate the accuracy of the productivity estimation. Table 4 compares the original operation versus the solution.

The essential findings revealed that the existing C&S task presented medium exposure to musculoskeletal risks, while the proposed change (use of a saw cart) was assessed as presenting a low exposure to musculoskeletal risk (Table 3). The labor time of the original C&S task found the total labor content of the process to be 33.09 minutes with 21 substeps to complete the process. The predicted labor time was assessed to be 14% more productive at 28.4 minutes with 14 substeps (Table 4). The validated saw cart cut the number of substeps from 21 to 12 and was 14% more productive than the existing C&S task (Tables 4 and 5). The difference in labor time between the proposed and validated labor time was only off by 1.4% and two steps.

Two conclusions were formulated as a result of the exploratory analysis. First, the process of performing a task analysis, risk assessment and labor time estimation was a relatively efficient activity. The analysis and risk assessment of the existing C&S task took less than 1 hour to complete. However, the BasicMOST measurement was more complicated and time consuming. According to Zandin (2001), a BasicMOST analysis can typically take 10 hours for every hour of measured work. For this study, the complete original assessment took less than 6 hours to analyze.

Second, proposals to reengineer a process and incorporate new equipment are a dynamic process, especially in the conception phase. The design process then becomes an iterative process requiring constant readjustment and reevaluation as the proposal becomes a reality. The ergonomist or safety specialist should be engaged early in the design phase in order to advise management how the design modifications will likely affect musculoskeletal risks and labor times. In addition, it would help to simplify the methodological aspects of making investments in ergonomic practices, while making the economic and operational implications of the investments transparent.

Conclusion

There should be no denying the direct and indirect benefits derived from investments in ergonomic practices (Beavis & Slade, 2003; Seeley & Marklin, 2003; Yeow & Sen, 2003; Drury, 2000; Alexander, 1998; Bencivenga, 1996; Hendrick, 1996). However, simply upholding the direct and indirect benefits of musculoskeletal solutions without providing a compelling business case will likely fall short in the pursuit of investments.

In addition, it can be difficult for ergonomic investment proposals to compete with other investment alternatives. In this case, plant management wanted to invest in ergonomic improvements for the same reasons it made other strategic investments within the plant—management expects those investments to contribute to operational performance, enhance economic performance, reduce risk to resources and lower the firm's contingent liability.

The study also found that plant management was interested in investing in practices to confront and manage MSDs, but prior experience suggested that the process was complicated and presented methodological issues and economic and operational implications. Despite this, the plant had invested in the past to counteract MSDs and expressed a desire to better understand the economic impact of these investments.

This case study is an exploratory step toward understanding how to formulate a compelling strategy to help plant management simplify the methodological aspects of making musculoskeletal investments. In addition, it was important to make the economic and operational implications more transparent. During the study, the researchers recognized the management acumen and technical knowledge required by plant staff to confront and manage musculoskeletal risks and understand how MSDs can affect employee performance. It could be reasoned that the plant's operating performance and worker MSD risk could be affected by management's perceptions of the need for ergonomic investments and interventions.

With this proposition in mind, the study team conducted a single case study of the activities that typically would drive an ergonomic intervention and an exploratory empirical test of the parts of the ergonomic intervention to provide observed data support for the proposition. The result is a discussion of the role that a well-designed and implemented ergonomics strategy, informed by exploratory analysis and observation, can play in preventing MSDs and improving operating performance.

The case study contributes in several ways. For educators, it adds a level of understanding of how to arrange learning conditions that specifically focus on an alternative way of gaining plant management support for investments in ergonomic interventions. It also provides insights on the connection between ergonomics and operational performance; this is an

A saw cart (Photos 3 and 4) was recommended because it would automatically make the panel cuts—rather than having an employee make the cuts with a saw. This would isolate employees from the identified musculoskeletal risk factors.

Table 4

Existing vs. Solution

Category	Existing	Solution
No. of hours worked per day	8	8
Employee fully loaded labor rate	15.88	15.88
No. of panels manufactured	10	14 to 15
Capital required (saw table)		~$1,500 material cost ~80 hours labor cost
Functional task analysis of operating tasks	21 substeps	14 substeps
Musculoskeletal risk	REBA = medium to high risk ACGIH HAL TLV= medium risk SI = some to moderate risk	REBA = low risk ACGIH HAL TLV= acceptable SI = safe
Labor time (minutes)	33.09	28.8
Productivity increase		14%

Table 5

Process Change Performance

Task	Task	Subtask	Labor time (TMU)	Labor time (minutes)
1. Move panel to workstation	1.1	1.1.1 Prepare panel for seam inspection	11800	**7.08**
		1.1.2 Inspect seams	2800	**1.68**
		1.1.3 Place panel on cut table	12400	**7.44**
2. Cut panel	2.1 Check panel placement	2.1.1 Check one side of panel relative to table	410	**0.246**
		2.1.2 Check second edge of panel relative to table	410	**0.246**
	2.2 Cut panel	2.2.1 Cut first end	2320	**1.392**
		2.2.2 Cut both sides	4960	**2.976**
		2.2.3 Cut last end	2180	**1.308**
3. Sand panel	3.1 Preparation for sanding	3.1.1 Prepare for sanding	420	**0.252**
	3.2 Sand seams	3.2.1 Sand 13 half seams	5083	**3.0498**
		3.2.2 Sand 13 half seams (*other side of panel*)	4823	**2.8938**
	3.3 Post sand	3.3.1 Remove sanders	420	**0.252**
Total labor time (minutes)				**28.8**

underresearched link that demands clarity for educators and plant managers alike.

For students, it can help jumpstart their career by helping them focus on addressing operational activities that are linked to work-related MSDs. It may also serve as a springboard to additional research, such as the empirical testing of various assessment techniques and tools employed during the case study.

For plant management personnel, this case study serves as a business model for recognizing ergonomic interventions as an economic opportunity, not a cost or inevitable regulatory threat. This is an important business aspect that ergonomic specialists should make more transparent to plant management.

Information and data that should be considered important in helping to make the business case includes 1) estimating the probability that MSDs will occur; 2) calculating the productivity impact, the extent of worker adversity and disability, and range of costs expected as a result of an MSD; 3) calculating the cost of confronting and managing MSDs; and 4) estimating enhancements in worker protection and productivity expected from investments in ergonomics solutions. ■

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