CONSTRUCTION INDUSTRY INSTITUTE

An Analysis of Multiskilled Labor Strategies in Construction

Research Summary 137-1

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An Analysis of Multiskilled Labor Strategies in Construction

Prepared by
The Construction Industry Institute
Multiskilled Craft Capabilities in Construction Research Team

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Executive Summary

Labor productivity, craft training, and the declining number of entrants into construction crafts present critical challenges for our industry today. One solution which may positively effect many labor issues is to better utilize the skilled workers currently in the industry through the development and use of multiskilling. A review of studies over a 10-year period from the manufacturing area indicates that multiskilling strategies resulted in process improvements and technological innovation.

The scope of this study included a detailed project analysis of a single domestic, grass roots, open shop industrial construction project and the exploration of currently used multiskilling applications in construction. Benefits of multiskilled labor utilization were demonstrated with regard to total project labor cost, employment opportunities for construction craft workers, and other industry labor issues. These benefits included conservative estimates of five percent total labor cost savings, a 35 percent reduction in required project work force, a 47 percent increase in average employment duration of each worker, and an increase in wage/annual earning potential for multiskilled construction workers.

A system for estimating the potential project benefits of alternative labor utilization strategies was developed. All labor cost factors in the cost model were identified and developed by the industry research team. The cost model is used in conjunction with labor data from the project schedule to quantify the potential cost savings from a multiskilled labor strategy.

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Introduction

Definition of Multiskilling

Multiskilling is a labor utilization strategy where workers possess a range of skills appropriate for more than one work process and are used flexibly on a project or within an organization. Workers can be assigned to construction tasks based on their ability to perform the needed skill/task, not limited to traditional job boundaries. Based on the flexible application of skills that the worker already possesses or is willing to acquire, workers can be an effective and productive contributor to the output of several work processes, although they may not achieve mastery-level skill in all areas.

Labor productivity, training, and the declining number of trade entrants are critical needs facing the construction industry. Alternative labor utilization strategies and modified industry labor practices are needed if the industry is to address these growing concerns effectively.

Specialization strategies have been identified in other industries as a restricting factor in the implementation of new technology and in the development of process-based innovation. These studies indicate that when work boundaries are crossed, shared, merged, or eliminated, new opportunities for innovation arise.

Currently used craft delineations, in practically all sectors of the industry, have changed very little in their organization by the same craft groupings. As a result, little experimentation with alternative strategies has been tried. For example, existing training programs, skill evaluation systems for the purpose of determining pay, licensing practices, recruiting practices, company employee database systems, managerial work assignment practices, and company cultures make a major strategy shift in labor utilization difficult. These old craft/trade paradigms have proven to be resistant to change even.

One factor that limits the implementation of alternative labor strategies is the absence of a reliable model to predict the potential benefits or penalties associated with a change in labor utilization. Construction industry analysts and practitioners have focused their attention on skilled labor availability for many years now. Falling numbers of new trade entrants and low construction unemployment rates increasingly indicate that there are not enough skilled workers to meet rising demand. Part of the problem in meeting demand is the unstable and short-duration job assignments. New entrants into the work force are seeking better job stability. It is believed that the solution to the skilled labor shortage is to look for ways to better utilize the skilled workers already in the industry and to improve job stability.

Multiskilled labor utilization strategies have been successfully implemented in many industries and many countries. In these instances, a multiskilled work force has been identified as a contributing factor to economic development, improved international competitiveness, and increased profitability.

Research Objectives

The following key objectives were used by the research team to guide this study:

1. Investigate the extent to which multiskilling has been applied in the construction industry.

2. Develop a system of craft loading and project cost analysis to measure the impact of alternative multiskilling strategies.

3. Investigate the potential benefits or penalties and feasibility of using multiskilled labor strategies in the construction industry.

4. Analyze the study results, draw conclusions and make recommendations for industry action and future research needs.

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Methodology

The scope of this research includes the development of a project level analysis system, the estimation of multiskilling project impacts, and the development of supporting evidence of current multiskilling practices. Two research techniques were incorporated in the study: (1) a detailed analysis of a single project application, and (2) a current practice survey of existing construction multiskilling applications. A project was selected that allowed the exploration of alternative multiskilling strategies unrestrained by complications imposed by subcontracting practices, or the consideration of jurisdictional lines and work rules. The current practice survey included project applications from all lines of contracting.

The following list of research tasks provides an overview of the research process:

1. Conduct an in-depth investigation of existing literature documenting the theory of multiskilling as well as previous applications of multiskilling (emphasis on construction applications).

2. Develop a system of labor analysis, and determine baseline worker hour requirements for the sample project.

3. Define alternative multiskilling strategies to be assessed in this research.

4. Repeat the labor analysis for each multiskilling strategy using the new craft descriptions defined for each strategy.

5. Develop an economic benefit model to measure project impact and conduct a comparative analysis of alternative multiskilling strategies.

6. Assess the impact of multiskilling on total labor cost, employment duration, and strategic human resource management policies.

7. Analyze results, draw conclusions and identify possible impediments to industry application.

Use of the CII Model Plant

The CII Model Plant was selected because of the availability of detailed project level data and wide industry consensus on the representative value of the project. The Model Plant is a virtual petrochemical processing facility developed in 1985 by CII member companies to provide, at that time, a standardized physical facility for productivity measurements. Since its development, the Model Plant has been used in two benchmark productivity studies and in an analysis of multi-functional equipment. The adoption of the Model Plant provides a proven base for analysis and provides clear boundaries to the scope definition of this research.

The Model Plant consists of nine separate areas including a refractionation unit, tank farm, compressor unit, two turbine generators, underground piping, pipe bridge, and a complete civil site package. The documentation from the Model Plant used to conduct this study includes: a detailed quantity survey, a work-hour labor estimate, a historic cost estimate for approximately $70 million of the total $85 million project value, a 78-week project schedule, and 87 representative drawings documenting all major components of the project.

Using the Model Plant as a basis for analysis, existing project data and project management tools were used to develop labor data representing current industry staffing practices. Opportunities for multiskilling were identified and theoretically implemented on the Model Plant project. A comparative benefit analysis was used to quantify project impacts and identify a possible “best strategy.”

Labor Utilization Documentation

To conduct repetitive project labor analyses, Primavera Project Planner (P3) was chosen because of its resource allocation features. P3 resource tools were used to define detailed craft resources and assign them to each activity in the Model Plant schedule. Resource profile reports in P3 were used to produce individual project "craft curves" for the baseline data and each multiskilling strategy (Figure 1). Data from these resource curves provide input values for the economic analysis. Descriptive values taken from the craft curves include:

1. the number of contractor initiated hires and fires,
2. the average employment duration of craft workers on the project, and
3. the frequency distribution of employment duration for each strategy.

Labor resource profiles generated from the schedule captured small increases and decreases in craft work force demand on a weekly basis. Resource leveling techniques were applied to represent probable hiring/layoff practices more accurately.

The automated leveling features of P3 minimize the demand fluctuations of individual resources by altering the start dates of activities within the bounds established by activity restraints and logical relationships built into the schedule. Electronic leveling was performed before the individual craft curves were plotted. A second manual leveling pass was then used on each craft to approximate the staffing discretion that project managers and superintendents have at the field level.

From each of the many leveled resource curves in the baseline and multiskilling data, the total number of contractor initiated hires/fires and the average employment duration of workers was calculated for use in the comparative cost model. Hires and fires were calculated by counting the incremental increases and decreases along the Y-axis. The

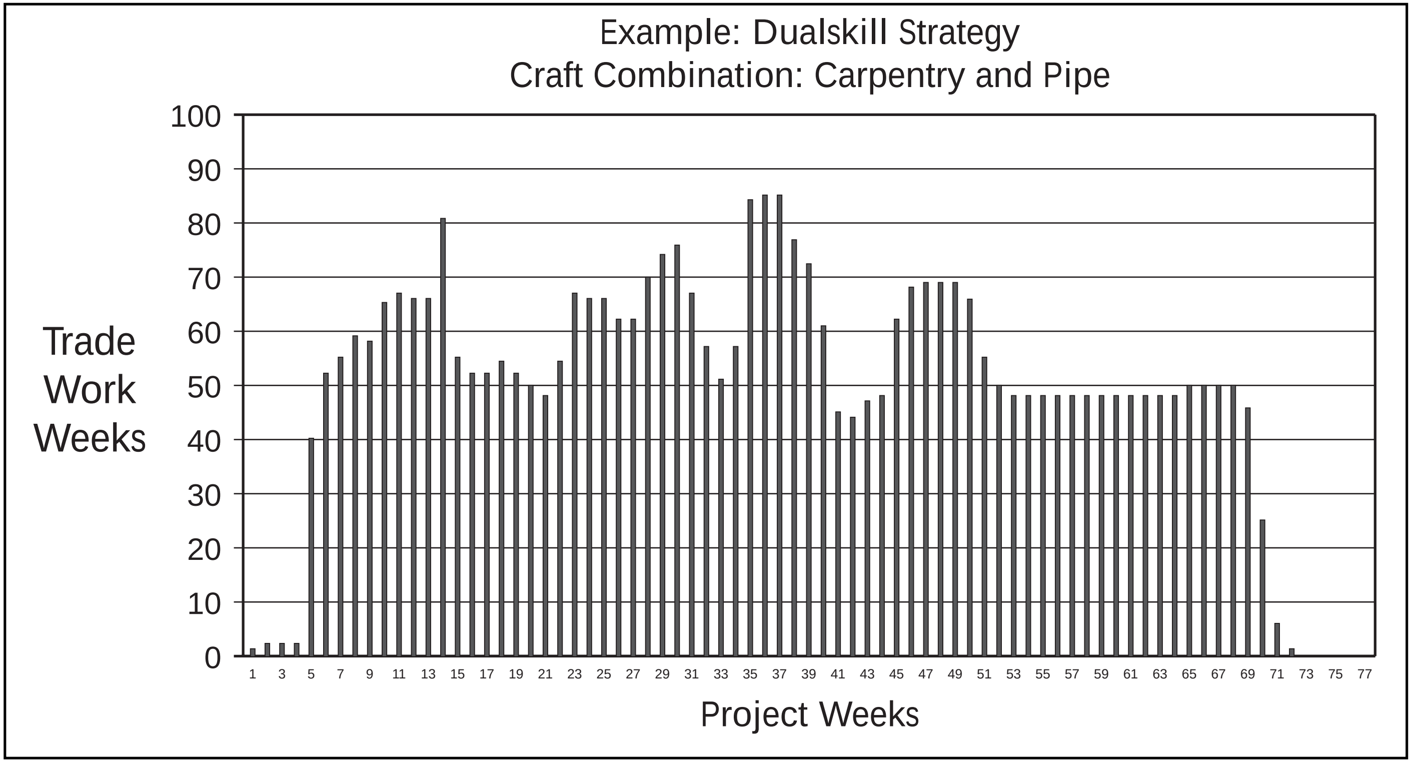

Figure 1. Sample Craft Curve Showing Manual Resource Leveling

average employment duration of all trades was calculated using a weighted average of employment duration read from the X-axis. A “first-in, last-out” assumption was used in the duration calculation. This implies that contractors hire the most desirable workers in each skill level first, and then attempt to retain these workers until no additional work in their craft or skill group is needed. For each of the labor strategies tested, the total project work-hours remained constant (productivity improvement was assumed to be zero).

Development of the Baseline and Multiskilling Labor Strategies

To document “current” labor utilization practices, three companies with extensive petrochemical background were surveyed to obtain independent estimates of labor resource requirements. Individual staffing plans were compared and a single staffing plan was selected as the most representative plan. Each of the three companies that participated in the baseline staffing exercise were asked to “staff” all schedule activities with the crews or trade workers typically used by their firm to perform the work. Three general skill levels for each craft were recognized in the staffing plan: foremen, craftsmen, and craft helpers.

Seventeen craft groupings were identified and used by the companies participating in the staffing exercise. Both peak and average craft usage was calculated for each craft grouping used in the baseline staffing plan. These figures compared favorably with the original Model Plant estimates and therefore validate the reliability of the baseline plan as “representative” of industry practices.

Four multiskill labor utilization strategies were explored in this research. Using the Model Plant schedule as a guide, a revised field staffing plan was developed for each of the four strategies. Individual craft curves were produced and comparative summary data were calculated from each in the same way in which they were developed from the baseline data.

Dualskills: The demand-driven "dualskill strategy" identifies craft combinations with complementary work loads so that workers arrive on the project and remain longer by working on multiple tasks before demobilizing. Table 1 provides summary data.

To identify the best dualskill combinations, baseline craft curves were matched together to create more stable demand patterns (longer and flatter curves). No consideration was given to how likely the combinations were to occur or how similar the trades were to each other, only the number of workers needed and the timing of their use was considered in the matching process. Note that this strategy is a project specific solution which would vary from project to project. Eight dualskill labor classifications were generated in the Model Plant exercise.

It is noted that some dualskill combinations are feasible while others appear to have no practical application. It also should be noted that some combinations it implemented could be a demonstrator, such as a welder/general laborer. Additional higher salary costs could be the case when utilizing a skilled welder as a semi-skilled laborer. Baseline crafts that do not complement demand for any other craft group may reflect crafts that would remain single-skilled or may become subcontracted/temporary labor under this labor utilization strategy.

Four Crafts-A: Industry experts indicated that craft workers could be grouped into four general classifications which captured not only the phased nature of a process facility, but also skill complexity and craft similarities. The four multiskilled craft groupings include: civil/ structural workers, general support workers, mechanical workers, and electrical workers. In the "Four Crafts-A" strategy, all three skill levels of each craft are included in the new multiskilled grouping. For example, the helper, craftsman, and foreman levels of the pipefitter craft group were included in the newly defined mechanical craft grouping. Table 2 provides summary data.

Table 1. Summary Data for Dualskill Labor Strategy

Dualskill Staffing Plan Craft Classification and Summary Craft Usage		
Craft Classification	Peak Craft Usage	Average Use for Active Period
Welder/General Laborer	69	34
Electrical/Insulation Worker	43	24
Rigger/Equipment Operator	36	18
Carpenter/Pipe Worker	85	53
Surveyor/Instrumentation Worker	12	7
Iron Worker/Structural Steel Erector	46	19
Truck Driver/Crane Operator/Painter	35	19
Concrete Finisher/Millwright	41	15

Table 2. Summary Data for the Four Crafts-A Strategy

Four Crafts-A Staffing Plan Craft Classification and Summary Craft Usage		
Craft Classification	Peak Craft Usage	Average Use for Active Period
Civil/Structural carpenter, iron worker, concrete finisher, structural steel erector	99	37
General Support laborer, equipment operator, truck driver, crane operator, rigger, surveyor, painter	85	43
Mechanical insulation worker, millwright, pipe worker, welder	132	67
Electrical electrician, instrumentation worker	35	20

Four Crafts-B: The "Four Crafts-B" strategy is a model where the helper-level workers are removed from the originating craft group and are added to the "general support" multiskill craft grouping because all helper-level workers have similar duties. Table 3 provides summary data.

Because new recruits will be assigned as helpers to many craft workers during their first years, they will have the opportunity to observe each craft option. When new recruits are ready for more advanced training, they can make informed choices of craft discipline(s) based on actual experience.

Theoretical Maximum: The final strategy evaluated in this study was the "Theoretical Maximum" multiskilling strategy (see Table 4). This strategy assumes that there is only one craft classification for the construction industry, "construction worker." All construction workers in this approach are assumed to be fully multiskilled; however, three levels of skill acquisition are still recognized. This strategy identifies a theoretical maximum to the benefits identified and quantified in this study. Development of a fully multiskilled work force is probably not economically efficient or desirable. However, the theoretical maximum provides a relative measure of benefits achieved by each of the other multiskilling strategies.

It is believed that extreme skill aggregation will eventually produce diminishing returns in project and industry benefits because:

1. Infrequent use of skills makes maintaining some skills difficult.

2. Constant movement of workers on the site may become disruptive.

3. Training costs may eventually outweigh the benefits of the increased flexibility provided through multiskills.

Table 3. Summary Data for the Four Crafts-B Strategy

Four Crafts-B Staffing Plan Craft Classification and Summary Craft Usage		
Craft Classification	Peak Craft Usage	Average Use for Active Period
Civil/Structural carpenter, iron worker, concrete finisher, structural steel erector	64	22
General Support all helpers, laborer, equip. op., truck driver, crane operator, rigger, surveyor, painter	167	87
Mechanical insulation worker, millwright, pipe worker, welder	81	43
Electrical electrician, instrumentation worker	23	13

Table 4. Summary Data for the Theoretical Maximum Strategy

Theoretical Maximum Staffing Plan Craft Classification and Summary Craft Usage		
Craft Classification	Peak Craft Usage	Average Use for Active Period
Construction Worker carpenter, iron worker, concrete finisher, structural steel erector, laborer, equip op., truck driver, crane operator, rigger, surveyor, painter, insulation worker, millwright, pipe worker, welder, electrician, instrumentation worker.	296	160

Summary of Data: A comparison of key descriptive data taken from the craft curves of each labor utilization strategy (similar to Figure 1) reveals important trends. The total required work force to complete the Model Plant was reduced by 18 percent using the Dualskill approach, and 35 percent using the "Four Crafts-B" approach. In addition, the average employment duration of craft workers was increased 18 percent using the Dualskill approach, and 47 percent using the "Four Crafts-B" approach. Table 5 provides a comparison of the actual values from which these percentages are calculated.

Table 5. Summary Comparative Data for all Labor Strategies

Summary Data Values for the Economic Model Comparative Listing of Labor Utilization Strategies		
Utilization Strategy Name	Craft Hires	Avg. Employment Duration
Baseline	675 workers	18.6 weeks
Dualskill	555	22.0
Four Crafts-A	508	23.9
Four Crafts-B	436	27.4
Theoretical Maximum	366	33.0

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Project Cost Model

To quantify potential benefits of using a multiskilled labor strategy in construction, a model (equation) that includes hiring costs, direct wages, and many indirect labor costs was developed. To make the model an effective tool, it was designed to produce comparable values for any multiskilling strategy as well as original company data or industry standards. The model was developed as a mathematical calculation of total project labor costs. Calculation methods for specific cost terms in the model were formulated by researchers using input values obtained from company specific records, project specific data, and published industry standards.

Economic Equation

A graphic representation which identifies key input data sources and all cost terms of the total cost function is provided for illustration in Figure 2. Ten cost terms were used in the model to generate a total labor cost estimate for the Model Plant. A table of values used in the Model Plant analysis is provided in Appendix A with a definition of the cost terms shown in Figure 2. These values can be modified by another

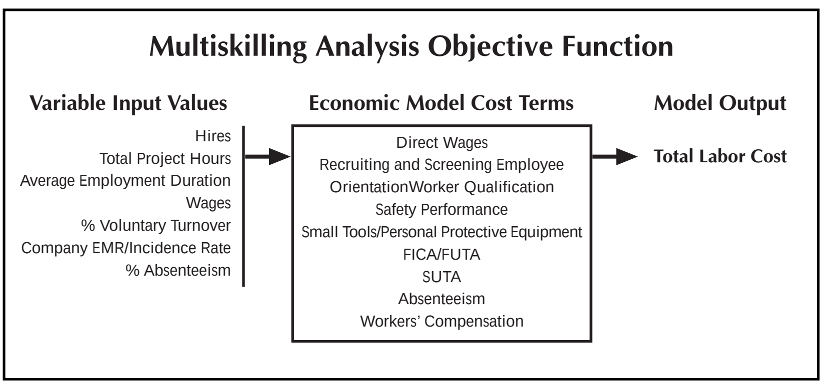

Figure 2. Graphic Representation of Cost Model

user to conduct any specific project analysis. The full mathematical development and formulation of each cost term is provided in CII Research Report 137-11.

Results of Economic Model

Each multiskilling strategy was evaluated using the cost model. All analyses were conducted assuming a zero percent productivity increase. This comparison isolated the labor cost savings of multiskilling associated solely with the more stable use of jobsite personnel. These benefits accrue from reduced turnover costs, orientation costs, screening costs, and others. Total worker hours required to complete the Model Plant project were held constant in all strategies included in this study.

Of the strategies evaluated in this study, the "Dualskill" strategy demonstrated the smallest labor cost savings. This strategy provided a labor savings of $260,187, approximately a three-percent reduction in total labor cost. The most successful multiskilling strategy tested was the "Four Crafts-B" approach, which provided labor savings of $432,035, approximately a five-percent reduction in total labor cost. When compared against the Theoretical Maximum strategy, the "Four Crafts-B" approach captured about 75 percent of the maximum potential savings (see Table 6).

Table 6. Total Labor Cost Savings Assuming No Productivity Improvement

	Labor Strategy				
	Baseline	Dualskill	Four Crafts-A	Four Crafts-B	Theoretical Max.
Cost Term					
Total Project Wages	$6,281,112	$6,281,112	$6,281,112	$6,281,112	$6,281,112
Project Safety	$136,116	$112,976	$109,301	$106,171	$88,203
Orientation Costs	$85,893	$70,623	$64,643	$55,481	$46,573
Recruiting/Screening	$236,925	$194,805	$178,308	$153,036	$128,466
Qualification Costs	$16,817	$15,062	$14,374	$13,321	$12,298
Small Tools and PPE	$462,794	$380,519	$348,295	$298,930	$250,937
Worker's Compensation	$1,086,004	$1,086,004	$1,086,004	$1,086,004	$1,086,004
FICA/FUTA	$717,169	$648,163	$653,304	$630,502	$603,527
SUI/SUTA	$108,527	$81,905	$84,294	$74,763	$63,653
Total Project Labor Cost	$9,131,357	$8,871,169	$8,819,635	$8,699,320	$8,560,773
Total Cost Savings (%)	0.0%	2.8%	3.4%	4.7%	6.2%

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Current Multiskilling Practices

Survey questionnaires were submitted and interviews were conducted with companies to capture the experiences of companies currently using multiskilled labor strategies. The surveys were used for three purposes:

1. To verify the results of the economic model.
2. To identify actual experienced benefits or negatives to the worker and to the project.
3. To identify potential impediments to widespread multiskilling implementation.

Five companies participated in this phase of the research yielding 13 usable surveys. Projects included in the survey results represent a cross-section of all labor sectors.

Benefits

The most commonly reported worker benefits were increased employment duration, improved marketability, and increased sense of security/satisfaction (+83 percent respondents). The most commonly reported project benefits were increased flexibility in worker assignment, lower turnover, smoother work flow with less dead times between tasks, fewer workers needed to complete the project, and lower costs to the owner (+83 percent respondents).

Barriers

Each problem included here was independently identified by more than 67 percent of the users. First, users felt that complex tasks did not lend themselves to multiskilling. Secondly, recruiting multiskilled workers and accessing adequate information regarding the skills of each worker are problems. Third, users saw that deterioration of infrequently used skills was inevitable. Some problems identified less frequently, but still significantly, were local licensing requirements, difficulty in developing multiskilled craft tests, and compensation management/policies.

Three general models for compensation were used. Some users have a single multiskill pay bracket. Others divide workers into two or three multiskilled crafts, each having a pay bracket assigned to the classification. Finally, some use a base pay with additional compensation for each additional skill in which the worker is proficient. All companies participating in the survey provide skills training for employees. In all cases, the employer selected the skill areas chosen for training; however, 50 percent indicated that employees may choose whether to participate. Half of the participating companies used on-the-job training and half used formal craft training techniques.

Finally, 67 percent of participants actively recruit multiskilled workers, while 17 percent recruit primarily from “single crafts” and develop multiskills in-house.

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Benefits and Impediments

Project Benefits

The primary project benefit is the reduction in total project labor costs as discussed in the Project Cost Model section. Project site safety is improved due to increased employment duration on the site. Previous studies have shown that most accidents occur in the first months on a new site.

Multiskilling provides an environment where duration in employee assignment increases and therefore individual break-in periods are reduced. The ability of multiskilled employees to perform a larger portion of the work has led to an observed increase in productivity by decreasing idle time and transition time between job areas or work groups.

Worker Benefits

A benefit of increased annual employment with the same company is also indicated. Because workers are trained to perform multiple tasks, they can be employed through many phases of the project. This results in less time spent unemployed. Employers also have an increased economic interest in retaining their multiskilled workers from project to project. The combination of these factors is likely to provide full annual employment.

A major benefit accruing to multiskilled workers is increased wage earning potential. Increased versatility and skill adds value and in some cases was used to negotiate modest increases in hourly wages. It is believed that the cost of multiskill training will be offset by a reduction in the per worker training costs as workers carry many fundamental skills from their primary craft into secondary skill areas.

Industry Benefits

It is believed that multiskilled labor utilization strategies may also have a significant industry impact. Due to improved utilization of existing workers, a reduction in the demand for new industry entrants is expected. It is also believed that the industry will hold greater appeal to young workers because of the development of additional career-type employment opportunities and increased job stability. Multiskilled construction workers can continue to develop and broaden their skills, their earning potential, and should experience expanded career options throughout their construction careers.

Potential Impediments

A work force “paradigm shift” is required throughout the industry. To utilize a multiskilled labor strategy, employers will have to alter their screening and hiring, compensation, staffing, and project management practices. In some sectors, owner practices that are designed around traditional craft definitions will have to be modified to fully utilize a multiskilling labor strategy (i.e., owner procurement packages, specification of number and types of trade workers, and work reimbursement issues).

The availability of appropriate training curriculums will also impact the successful application of multiskilling strategies. Initial resistance to broad changes in labor strategy is likely to be experienced, however, survey data indicates that individual worker resistance may be very low and that managerial resistance can be reduced with good implementation training. There is also likely to be varying levels of implementation difficulty between maintenance and new construction applications. More flexible systems will be needed to manage a multiskilled work force in non-maintenance construction sectors.

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Multiskilling Implementation

Through the surveys of current multiskilling users, and interviews with managers in these organizations, some key similarities were observed with respect to company implementation. The flow chart in Figure 3 (see next page) summarizes the general concepts and sequences associated with successful strategic changes. This general model is proposed as a starting point for future research to develop implementation guidelines for multiskilling users in construction.

After the skill groupings have been determined, appropriate recruiting, training and compensation procedures must also be developed. To place workers into appropriate training and to insure that tasks are not assigned outside worker capabilities, a formal skills assessment procedure is also needed.

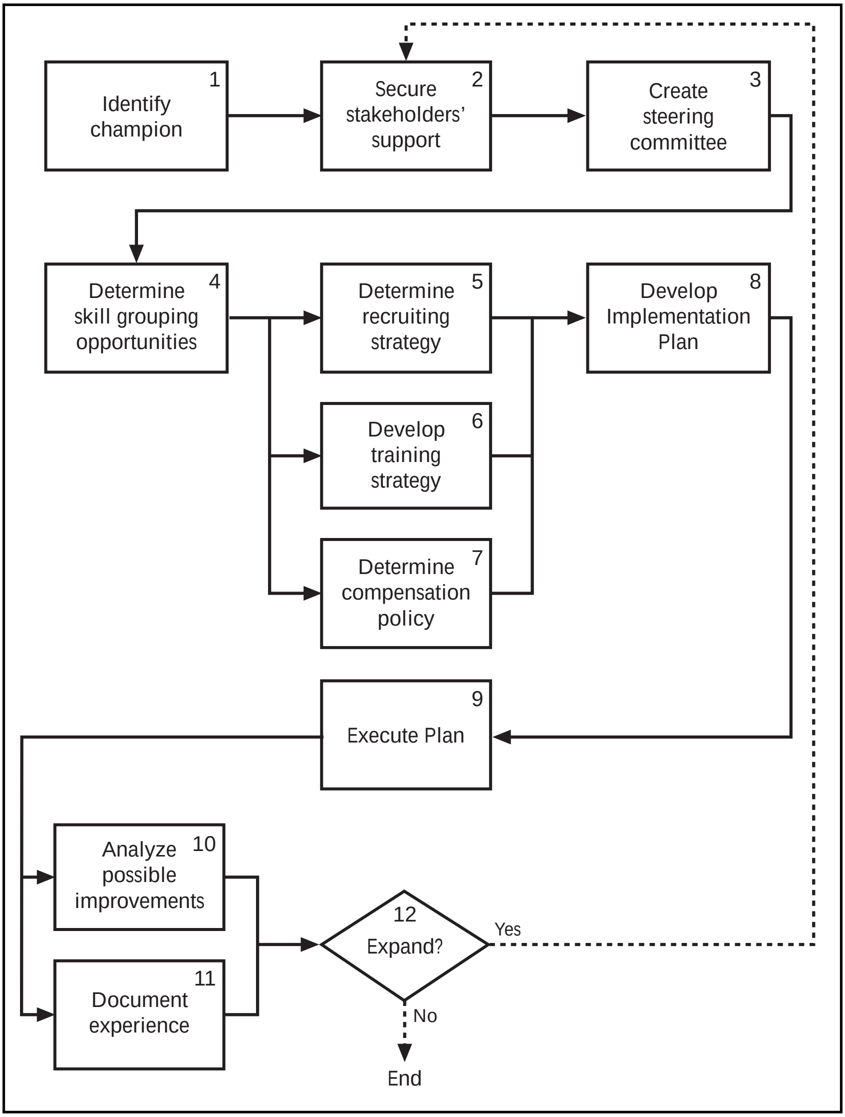

Figure 3. Multiskilling Implementation Flowchart

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Conclusions and Recommendations

Several conclusions can be drawn from the research:

1. Multiskilled Labor Utilization Strategies can provide significant project benefits including an estimated five percent total project labor cost savings and a 35 percent reduction in required project work force, when assuming no productivity variation.

2. Multiskilling can provide significant worker benefits including increased employment duration (18–47 percent), leading to more stable and constant annual employment and increased wage/annual earning potential.

3. Multiskilling strategies increase the favorability of new craft entrants and better utilize existing workers.

4. Project and company systems must change to support multiskilling as a competitive strategy. This will likely include: training and employee development, employee compensation, recruiting and hiring practices, management information systems, and project execution strategies.

5. A total project labor cost model was developed that can be used to evaluate the potential benefits of alternative multiskilling strategies. This model may be used by researchers, individual companies, or training providers in designing alternative labor strategies.

Multiskilling is a promising labor strategy that should be considered by companies as a potential competitive strategy. Additional research is needed to measure the productivity impact of multiskill strategies reliably. Additionally, a cost model for training and implementation is needed to support cost/benefit analysis and return on investment.

Appendix A

Table A-1 provides the values and a description of each value that was used in the total project labor cost model. Each of these values was used in one or more of the cost terms illustrated in Figure 2 of the body of this paper. Each cost term in the model is listed in this appendix with descriptions providing a detailed explanation of their development. These cost terms were used to evaluate the total project labor costs associated with each labor strategy tested in this research.

Table A-1. Summary of Model Plant Analysis Values

Values Used in the Model Plant Analysis	
Description	**Value**
Total Project Hours	484,289
Average Accident Cost	$21,133
Company Incidence Rating	2.660000001
Voluntary Turnover Rate	0.15
Percent Absenteeism Expected (as a decimal)	0.02
Recruiting and Screening Costs	$300
Qualification Costs for Employees (safety)	$25
Percent of Hires Who Must Attend Safety Class	0.500000001
Number of Welders from Craft Curves	71
Hours Spent to Qualify Welders	4
Percent of Welders Rejected	0.15
Qualification Costs for Welder Employees	$125
Cost of Small Tools and Personal Protective Equipment	$586
Hours for Employer Qualification Requirements	8
Experience Modification Rate	0.700000001
FICA Rate	0.0765
FUTA Rate	0.062
Maximum Taxable Wages for FUTA calculation	$7,000
Maximum Taxable Wages for SUI calculation	$9,000
SUI Rate	0.027
Weighted Average of Project Wages	$12.97
Orientation Costs	$108.76

Direct Wages Cost Term: Direct project wages are a function of total project work-hours and the average wage of trade workers. The "Average Project Wage" for this analysis is $12.97 based on a weighted average of the trades used in the Model Plant. Current wage data was gathered from research team members in Houston, Texas, the theoretical location of the Model Plant.

Recruiting and Screening Cost Term: This cost is applied to all hires and attempted hires and replacement workers for voluntary quits. Voluntary turnover rate for this analysis is assumed to be 15 percent. Based on data provided by the research team, a per hire cost of $300 is used. A five-percent rejection rate has been assumed in the model. Recruiting and screening costs may include application, interview, reference checks, physicals, respirator tests, drug screening, skill or performance testing, lead level testing, hearing loss tests, asbestos exposure tests, and the ancillary costs of administering any of these items.

Employee Orientation Cost Term: Employee orientation costs are calculated based on the total number of hours spent in any form of company or project specific orientation. Only the direct wages of the new employee and a minimal materials expense are included in this cost term. The Model Plant analysis includes eight hours of orientation and/or reduced productivity hours and a five dollar material expense.

Worker Qualification Cost Term: Worker qualification costs may arise from owner initiated requirements or from state or local regulatory requirements. Two such requirements are typical of the Houston area petrochemical construction sector. First, all individuals at the project site must have completed the Houston Area Contractors Safety Council training and examination. It is estimated that half of all hires will require this course. The per student cost of this certification is $25. Additionally, it is estimated that half of the welders hired will require testing. The per welder cost for each test is $125. If the analysis project does not require any certification expenses or it is company policy not to pay for these items, the cost term would be entered as zero.

Safety Performance Cost Term: The safety performance cost term is based on a company and project specific estimation of the number of safety accidents likely to occur. This expected occurrence value can then be modified by a risk reduction factor based on the work force distribution of employment duration if an accident is expected. Average accident cost data are used to place a monetary value on the safety performance cost term.

A company provided incidence rating and the total number of project work-hours are used to calculate the expected number of safety accidents during the course of the project. For the Model Plant analysis, the CII member incidence rating of 2.66 was assumed. Average safety accident costs, as reported in a 1991 research study, are valued at $21,133. A risk reduction factor based on total work force risk is calculated for each multiskilled labor strategy. The employment duration distribution of each strategy is used in conjunction with a lookup table constructed from a Department of Labor curve entitled "Distribution of Injuries and Illnesses by Length of Service."

Small Tools and Personal Protective Equipment Cost Term: Each employee is provided minimum personal protective equipment (PPE) to work on a construction jobsite. Additionally, a cost is incurred for the loss/replacement of company owned small tools used on the job. The Model Plant analysis assumes a $500/hire cost for small tools and $86/person for initial PPE outfitting. Formula 6g provides the calculation methods for the Small Tools and PPE cost term.

FICA and FUTA Cost Terms: For 1996, the employers contribution to the Federal Insurance Contribution Act was 6.2 percent (Social Security) and 1.45 percent (Medicare). The maximum annual income subjected to social security tax was $62,700. In addition, the first $7,000 of wages paid to each employee is subject to Federal Unemployment Insurance (FUTA) at a rate of 6.2 percent. A breakeven number of weeks was calculated to determine the wages that are subject to these taxes. All direct wages have been assumed to be a tax FICA liability for our analysis (breakeven point was 50 weeks plus

1890 hours of overtime). To calculate the FUTA liability, the $7000 base was applied to all employees that were expected to work 13 weeks or more, the cutoff duration for maximum taxable earnings. Using the employment duration distribution, those employees who worked less than 13 weeks were charged a proportionately less FUTA tax.

SUTA Cost Term: The maximum tax liability base for state unemployment tax (SUTA) in Texas is $9000. A breakeven or cutoff value calculated to determine what wage portion is a full contribution liability. The cutoff value for the Model Plant is 18 weeks. A proportionately lower SUTA tax was paid for those working less than 18 weeks. Most state unemployment rates vary based on individual company experience. For the Model Plant analysis, the Texas employer entry rate of 2.7 percent has been charged.

Absenteeism Cost Term: The cost of absenteeism is a well documented labor cost. Based on data provided by research team members, a simplified calculation has been developed. Most contractors indicated that they "carry" an additional two percent of workers in order to accommodate absent employees without disrupting the flow of work. Each cost term associated with recruiting/ screening, hiring, orientation, or small tool/PPE costs is therefore increased by two percent. No additional wages or wages premiums are calculated because the wages paid to the additional workers are offset by wages not paid to the original employee.

Workers' Compensation Cost Term: Workers' Compensation Insurance is calculated at a unique rate based on a worker's trade classification and past company safety performance. An average industry contribution rate, 24.7 percent, has been used in the Model Plant analysis. To reflect the premium savings due to the better than average safety performance of most industrial contractors, an experience modification rate (EMR) of 0.7 was used.

Notes

Multiskilled Craft Capabilities in Construction Research Team

* Rebecca C. Burleson, Auburn University

Alan R. Burton, Cianbro Corporation

David Bush, Adena Corporation

Keith Byrom, H. B. Zachry Company

W. H. Clegern, Procter and Gamble Company

David Ellenburger, Stone & Webster Engineering Corporation

Bradley Funk, M. A. Mortenson Co.

* Carl T. Haas, The University of Texas at Austin

Mike Irish, John Brown

Ron Lawrence, Bechtel Group, Inc.

Rudy Peña, Houston Industries Power Generation

Jay D. Thompson, Watkins Engineers and Construction, Chairman

J. P. Zapke, Fru-Con Construction Corporation

Past Members

Michael Avant, Rust Engineering and Construction, past Chairman

* Principal Authors

Editor: Rusty Haggard

The Construction Industry Institute
The University of Texas at Austin
3208 Red River, Suite 300
Austin, Texas 78705-2650
(512) 471-4319
FAX (512) 499-8101

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