“COST EFFECTIVE ALTERNATIVE METHODS FOR STEEL BRIDGE PAINT SYSTEM MAINTENANCE”

CONTRACT NO. DTFH61-97-C-00026

COST MODEL USER’S GUIDE

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INTRODUCTION

A cost model for bridge painting maintenance was developed to aid specifiers in evaluating the costs associated with currently available painting technologies. A myriad of design approaches, surface preparations, and coating systems are currently available to engineers tasked with maintaining painted bridges. This cost model allows quick and easy comparisons between many of the current options for steel bridge painting. The information used for the model is based on actual field observations[1] and current industry practices. This "User's Guide" describes the model's primary components and features and the basic operation of the cost model.

The cost model accounts for the major factors that influence the overall costs of bridge painting. It has been developed as a multi-page Excel Workbook. Primary components include:

- **Project Input –** are variables that influence the Cost Objects. These are generally "constraint type" data such as the size and condition of the structure, and "selection type" data such as the various surface preparation methods.
- **Cost Objects –** show the contributions of various job processes to overall job costs. This provides the user with an appreciation for where the major costs of his particular projects lie. Cost Objects include items such as *labor, waste disposal, and materials*, and are greatly effected by the project methods selected.
- **Project Output –** details the results of the model's calculations. Each Cost Object is listed separately with total costs and unit costs ($\$/ft^2$).
- **Project Comparisons –** allow users to see the differences between three separate scenarios. A bar graph displays each Cost Object in a side-by-side comparison.
- **Cost Variables –** empower the user to customize the cost model to suite regional and operational variations.

This "User's Guide" contains three sections: a brief description of the cost model and its operation; guidance on how to use the cost model; and details of how the Cost Model builds an estimate and how users can customize the Cost Variables. Examples of some likely bridge painting scenarios analyzed with this Cost Model are provided in a separate report.

DESCRIPTION

This model was developed using data acquired from actual bridge painting projects throughout the United States. Data gathered on projects has been used to define default values for productivity rates, material consumption rates, etc. These rates appear as light

[1] All prices, costs and figures contained in this document and the Cost Model were verbally obtained in good faith from various contracting and supplier personnel. Although this model provides output detailed to the level of the penny in estimated cost, the actual cost of a job will be influenced by variables impossible to capture in this model. Therefore, Corrpro and The federal Highway Administration do not recommend that this spreadsheet be used to create detailed "Engineer's Estimates" for bridge projects.

blue fields on the “Input” spreadsheet of the model, and are described as “variable input” parameters. The workbook contains notes and descriptions throughout the Input spreadsheet. The default values and “industry standard” values are provided in these notes. The user can change or update these “values” based on local experience or as various methods become modified, more/less productive, or more/less expensive. In fact, it is expected that these default values will be updated by the user as data from a greater number of actual jobs is acquired.

The Cost Model runs calculations to build a time and materials estimate based on structure constraints and user inputs. The time required, or the duration of each phase of the work, is estimated using the production rates or speed factors in the Cost Model. This provides the labor durations for items such as mobilization, demobilization, containment construction, surface preparation, and paint application. Using these same input data, the materials required to complete the work are estimated. This includes items such as abrasive and water usage, gallons of paint required, and tons of waste produced.

The Cost Model output is divided among Cost Objects, which include:

- Labor
- Materials
- Equipment
- Waste Disposal
- Environmental, Health, and Safety
- Insurance
- Profit

Certain Cost Objects are calculated while others are based on user input or changeable default values (e.g., insurance and profit percentages are based on user defined values applied to subtotals of the other Cost Objects).

The pie chart shown in figure 1 is an example of the output from the Cost Model. This part of the Cost Model output breaks down the Cost Objects on a percentage basis. The output spreadsheet provides total costs, unit costs, and percentages for each Cost Object.

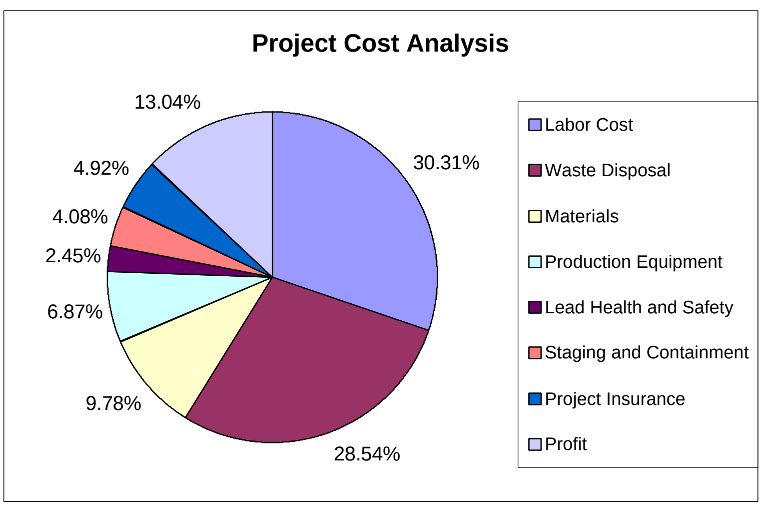

Figure 1. Example Cost Model Output Chart.

Once a user has viewed the output of a particular scenario, a macro button can copy these results to a comparison page. This allows for side-by-side evaluations of up to three separate scenarios. This allows users to compare sizes of structures or different surface preparations or different containment methods on a single page.

USING THE COST MODEL

The Cost Model workbook is comprised of seven (7) spreadsheets. Three of these are used for the calculations: Time, Materials, and Cost. The remaining four are used to collect data from the user "Input," view the Cost Model's results "Output," make comparisons among different scenarios "Comparison Page," and customize the calculation factors of the Cost Model "Cost Variables."

The model is designed to have users primarily interact with the Input page and view the results of various scenarios with the Output and Comparison Pages.

A reduced size copy of the Input page is shown in figure 2. Various fields on this page are color-coded to guide the user. Fields colored light blue are described as "variable input parameters." These represent production and cost rates for various aspects of the work. They contain default values generated from field research data on actual bridge projects and the "notes" accompanying these fields also contain some "industry standard" values. The user can either use these default values or modify these fields to reflect their own experience. Fields colored purple[2] are "input selections," and are pick list type entry fields (drop-down menus) that the user uses to quickly change the output of the Cost Model.

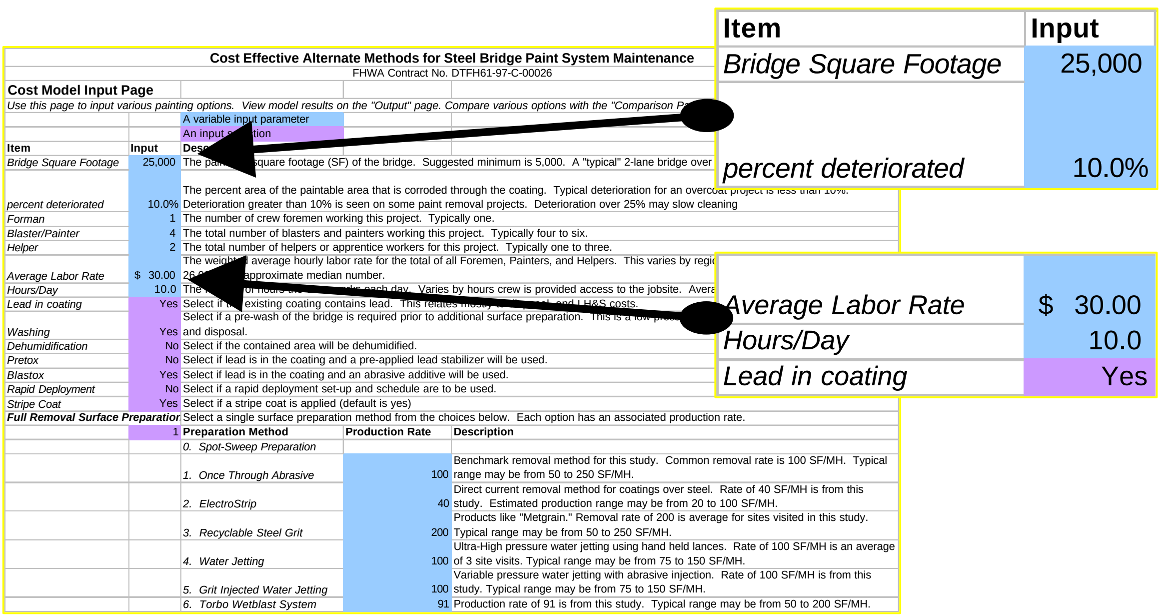

Figure 2. Examples of "Project Constraint" data.

Some of the "Project Constraints" are enlarged in figure 2 above. These items differentiate one project from another and should not be adjusted by the user when making comparisons between different painting strategies. Constraints include items

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[2] If this document is printed grayscale, the slightly darker shading represents purple.

such as; the square footage of the bridge, the percentage of the surface area deteriorated, weather or not there is lead in the existing coatings, limitations to containment or staging options, and labor rates or workday restrictions.

Once the constraints are defined and entered, the user may experiment with the variations possible with the Cost Model. These items are called the “Project Operating Parameters,” and include items such as; the choice of full removal or spot surface preparation, the productivity for each surface preparation option, the adjustable “time factors” for staging and containment, and coating system options (i.e., two or three coat system, stripe coat, application method, etc.). Some of the user changeable operating parameters are indicated in figure 3 below.

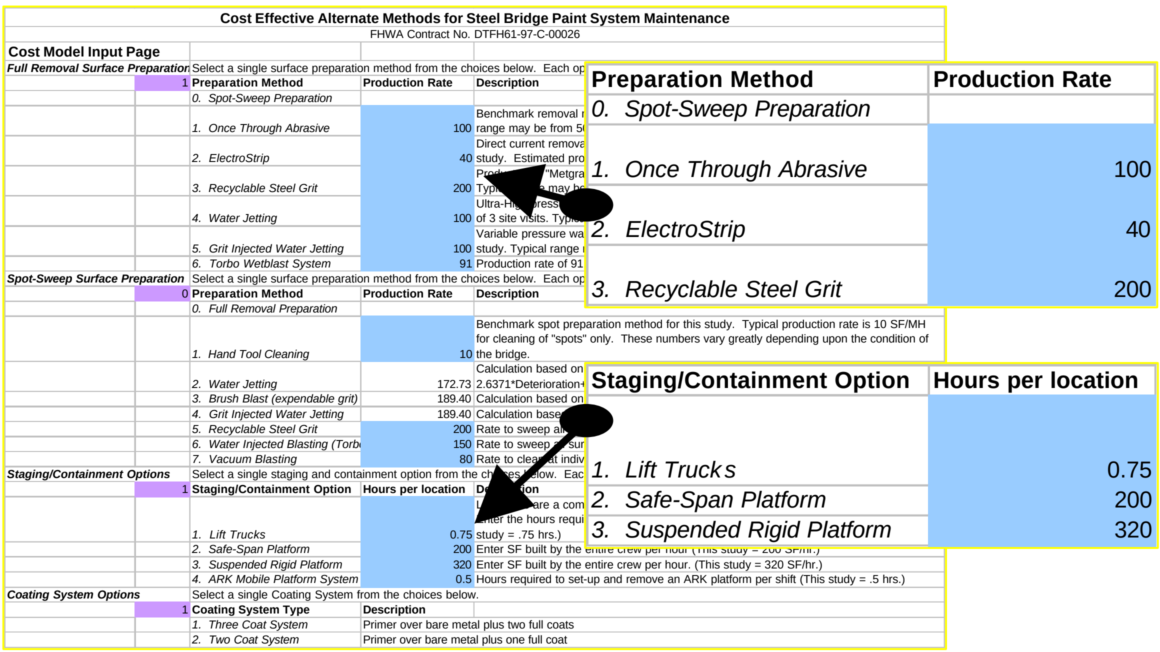

Figure 3. Examples of changeable “Project Operating Parameters.”

By changing any of the colored fields, the user can evaluate different scenarios. The user can analyze the comparative cost of competing surface preparation and coatings approaches on the same structure, or the user can vary the input parameters describing the structure to measure the sensitivity of each Cost Object on the size and existing condition of the structure. Both of these primary analytical operations can be done by varying the input in the colored boxes and the methodology chosen in the pick list boxes on the Input sheet.

In addition, the model can be customized by each user to reflect the individual experiences of each agency. For instance, the default values for productivity of each surface preparation method and coating application method can be modified in the light blue boxes by the user (see figure 3).

The results of user selections are viewed with the “Output” spreadsheet. Figure 4 shows some example data. Notice each Cost Object is delineated and broken down using a total

Cost Effective Alternate Methods for Steel Bridge Paint System Maintenance

FHWA Contract No. DTFH61-97-C-00026

Cost Model Spreadsheet - Results Page

For a Bridge Project with:

75,722 Paintable Square Feet

10.0% Percent Area Deteriorated

7 Persons in the Work Crew

The Costs to:

Full removal with once through abrasive

Contain using Lift Trucks

Airless spray apply a three coat system

are given below.

	Item Cost	Item Percentage	Cost / SF	Select below to send results to the "Comparison Page"
Labor Cost	$ 157,500.00	30.31%	$ 2.08	Copy as "Option 1"
Waste Disposal	$ 148,295.57	28.54%	$ 1.96	
Materials	$ 50,840.46	9.78%	$ 0.67	
Production Equipment	$ 35,705.66	6.87%	$ 0.47	
Lead Health and Safety	$ 12,750.00	2.45%	$ 0.17	Copy as "Option 2"
Staging and Containment	$ 21,193.88	4.08%	$ 0.28	
Project Insurance	$ 25,577.13	4.92%	$ 0.34	
Profit	$ 67,779.41	13.04%	$ 0.90	Copy as "Option 3"
Total Cost	$ 519,642.12	100%	$ 6.86	

Figure 4. Example data from Output spreadsheet.

amount, a unit price amount and a relative percentage of the entire project. There are automatically generated descriptions of the project constraints and the operating parameters on this page.

There are also three macro buttons on this page. Each of these copies the results currently displayed on the Output page to the "Comparison Page." When the user presses one of these buttons, the macro automatically copies and sends the output data and the focus of the program to the Comparison Page.

The Comparison Page displays up to three different scenarios on a bar chart. An example comparison is shown in figure 5. The Cost Model is currently set up to compare options based on unit cost and shows a comparison for each of the Cost Objects. This type of comparison shows the user how the selected scenario affects each of the Cost Objects.

Cost Effective Alternate Methods for Steel Bridge Paint System Maintenance

FHWA Contract No. DTFH61-97-C-00026

	Option 1	Option 2	Option 3
Labor Cost	$ 2.34	$ 3.15	$ 3.15
Waste Disposal	$ 1.96	$ 1.95	$ 0.01
Materials	$ 0.69	$ 0.74	$ 0.37
Production Equipment	$ 0.54	$ 0.94	$ 0.75
Lead Health and Safety	$ 0.21	$ 0.30	$ 0.30
Staging and Containment	$ 0.25	$ 0.40	$ 0.28
Project Insurance	$ 0.36	$ 0.45	$ 0.29
Profit	$ 0.95	$ 1.19	$ 0.77
Total Cost / SF	$ 7.30	$ 9.13	$ 5.93

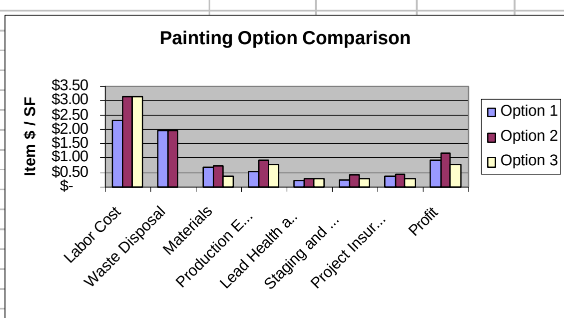

Figure 5. Example Comparison Page data.

There are four additional spreadsheets in the Cost Model. Three of these spreadsheets run the calculations for the Cost Model and the last spreadsheet allows users to customize the spreadsheet to their own unique circumstances.

The "Time" spreadsheet uses the input data to calculate the man-hours and time needed for each process, e.g., surface preparation, staging, painting, etc. The Time spreadsheet does not have any changeable input and all cells contain fixed calculations.

The "Materials" spreadsheet calculates material requirements, e.g., abrasive, water, paint, fuel, etc. It also calculates the waste that is generated from the process. All cells contain fixed calculations.

The "Cost" spreadsheet uses the data from the Time and Materials spreadsheets to calculate and sum up the direct and indirect project costs. These costs are then marked up for Insurance and Profit.

The last spreadsheet, "Cost Variables," contains over 140 variable inputs and is fully loaded with default information for ease of use. This data is used by the Time, Materials and Cost spreadsheet pages to calculate the estimates. A brief outline of some example Cost Variables includes:

- Surface Preparation Equipment Costs
- Staging / Containment Equipment Costs
- Material Costs and Usage Rates
- Disposal Costs
- Lead Health and Safety Costs
- Operating Cost Factors

COST VARIABLES – DETAIL

This section describes the calculation methodology and the various user changeable cost variables. In short, the adjustable numbers on the Cost Variables page are used to scale the calculations performed on the Time, Materials, and Cost pages. The latter three pages do not contain changeable inputs and are shown in the Cost Model for clarity only.

TIME CALCULATIONS

The Time spreadsheet calculates the project duration. It does this by calculating a specific duration for each phase of the work and summing all of the applicable phases based on the user input. Durations are calculated as follows:

- Surface Preparation – a duration is estimated based on the production rate, area to be prepared, and method of preparation.
- A specific time is calculated for pre-applied blast stabilizing agents (PABSA), that may be pre-applied to the surface to render lead-containing paint waste non-hazardous. The project constraints and an application rate are used in figuring this duration.
- Surface Washing – if this parameter is selected, a washing production is coupled with the size of the structure to calculate the duration.
- Painting Time – is based on the number of coats, application method, and production rate for each method.
- Containment and Staging Durations – are calculated based on "time factors," the containment method selected, and the size of the structure. Each duration is custom

calculated using factors like the hours required to move a lift truck that were observed during this contract.

- Rapid Deployment – is a work process that keeps the entire operation mobile and more importantly, completes a distinct area (cleaned and fully painted) within one work shift. If this methodology is selected, the composite rates observed during this contract are used to calculate the project duration.
- Mobilization time – is a set time calculated as the number of total man-hours for five work days.

For each of the time calculations, a result is generated in total man-hours. This is scaled to an appropriate number of "crew days" by the following formula:

$$CrewDays = \left(\frac{Man - HoursperItem}{(\#hoursperday - 2.5) * \#crewmembers} \right)$$

This formula best fit the authors' observations of actual work crews. On average, 2½ hours of each day were *not* spent performing the work involved with any of the Cost Objects. Any fractional *CrewDays* results are rounded up to the next integer. The total number of *Project Days* are summed based on the user inputs. This number is then converted to the number of *Project Months* and rounded up to the next whole month. Each of these durations is used in later calculations on the Cost Page.

MATERIALS CALCULATIONS

Each specific "usage rate" is combined with the project constraints and the operating parameters to estimate material quantities. The following are specifically calculated:

- Tons of abrasive – is based on a surface preparation method, size of the structure, usage rate, and weather or not an abrasive additive was used to render lead-containing waste non-hazardous.
- Gallons of water – is based on the cleaning methods selected, size of the structure, and the usage rates.
- Gallons of PABSAs – is based on the size of the structure and the specified pre-application parameters.
- Gallons of coatings – is based on the size of the structure, number of coats selected, application method, and coating system parameters.
- Gallons of fuel – is based on the project duration and a daily fuel usage rate.
- Tons of waste – is based on the project constraints, surface preparation method, and other operating parameters.

COST CALCULATIONS

The following Cost Objects are each individually calculated based on the project constraints and the operating parameters:

- Production Equipment Costs – are those associated with the cleaning and the painting of the structure. The user's input indicates what equipment is to be used. The number of equipment units is based on the crew size. The total cost is calculated by multiplying the number of project months by the costs of the various equipment.
- Staging / Containment Equipment – are those pieces of equipment used to access and contain the work. This cost is calculated the same way that the Production Equipment Costs are calculated.
- Cost of Materials – The Materials page provides the number of material units required. The total cost is calculated by multiplying the number of units by the unit costs provided on the Cost Variables page.
- Labor Cost – is calculated by multiplying the crew size, compensation rates, labor overhead rate, and project duration.
- Disposal Cost – is calculated by multiplying the tons of waste generated by the cost of disposal, while taking into consideration the waste classification (hazardous or non-hazardous).
- Environmental Health and Safety Cost – is primarily based on the project constraints (existing lead coatings?) and the duration of the project.

Each of these Cost Objects is individually summed on the Cost page and transferred to the Output page for display and conversion among different unit costs or percentages.

COST VARIABLES

The "Cost Variables" spreadsheet page contains sections where users may adjust the default information of the Cost Model to meet their individual circumstances (i.e., regional labor cost variations). Users may adjust any of the following:

- Equipment costs
- Factors affecting bridge constraints
- Material unit costs and usage rates
- Painting efficiency factors
- Disposal cost factors
- Operating cost factors
- Environmental health and safety costs
- Information on spot preparation production rates

Figure 6 shows where the user may adjust factors affecting equipment costs. These costs are amortized semi-monthly over five years at 7% interest based on nine working months per year. This assumes that the contractor has purchased the equipment and has sufficient work to expense the equipment over its useful life. Equipment prices were solicited from the manufacturers and quoted from participants in this contract. These prices were amortized and converted to a monthly cost. The initial cost, service life, and discount rate for each piece of equipment are changeable by the user.

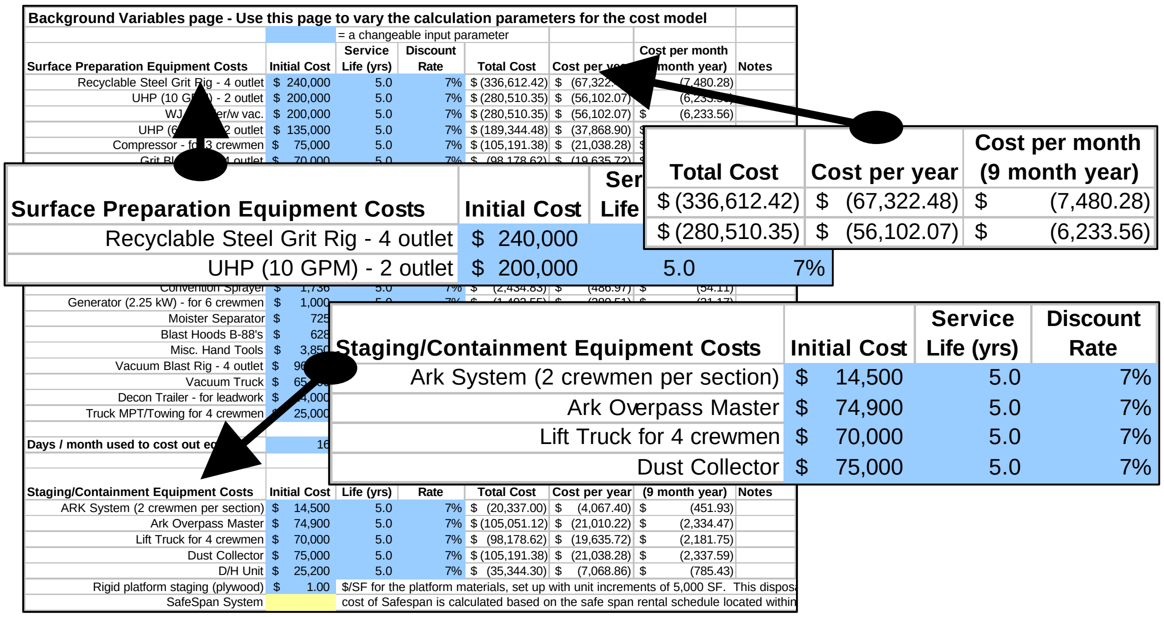

Figure 6. "Cost Variables" page showing example equipment costs.

The Cost Variables page also has several fields that are changeable so that the initial conditions (constraints) of a project can be accurately accounted by the Cost Model. These may include factors such as how long it may take to move containment enclosures and the thickness and density of the existing paint. Figure 7 shows some of these factors.

Equipment Sizing				
Lift Truck Deck Area	40	Length	12.0	Width
% Area Inaccessible to LT or ARK	15%	%-age		
ARK system Deck Area	40	Length	8.5	Width
Time Required to move Containment				
Spot Prep - hand/vacuum - from lift truck	0.25	hrs/move		
Full removal - dry methods - from lift truck	1.00	hrs/move		
Full removal - wet methods - from lift truck	0.50	hrs/move		
Pre-Existing Conditions				
Existing Paint DFT	17.50	mils	Thickness of the existing pa	
Existing Paint Specific Gravity	2.50	ratio	Specific gravity of the existin	

Figure 7. Example Project Constraints. Blue cells are adjustable by the Cost Model User.

The materials used on a bridge painting project are a significant cost. These are accounted for by providing places for baseline costs of consumable materials and supplies. Key to these are items such as abrasives, fuel, water, and coatings. Figure 8 shows how the user may adjust these parameters to further customize the output of the Cost Model.

Material Costs							
		cost/unit	unit				
Steel Grit	$	300	Ton				
Slag Grit	$	60	Ton				
Grit with Blastox	$	148	Ton				
Pretox	$	19.95	Gallon				
Water	$	0.027	Gallon				
Paint	$	30.00	Gallon				
Fuel	$	1.30	Gallon				
Other Misc. Items	$	200	Day (misc. sundries each day)				
Material Use/Application Rates							
Pretox Application Rate		3,000	SF/Hr				
Pretox usage rate		80	SF/gal	The ideal spreading rate at the specified WFT			
PreTox dry density		8.28	lb./gal	density of dried Pretox used in waste tonnage calculation.			
LPWC Production Rate		600	SF/Hr				
Stripe Coat Production Rate		2,600	Edges in SF shown / Hr				
RSG usage rate		0.50	lb./SF	This is the average RSG consumption rate for the project NOT the amount needed to clean each SF. If new RSG is specified for a project this should be higher, if new RSG is not specified .5 lb./SF is an accurate number.			
Once Through Slag usage rate		10.00	lb./SF	Average needed to clean each SF			
UHP water usage rate		3	GPM	1.80	gal/SF full remc	1.04	gal/SF spot work
LPWC usage rate		0.15	gal/SF				
Water with Grit injection - Water use		0.123	gal/SF				
Water with Grit injection - Grit use		1.00	lb./SF				
Grit blast with Water injection - Grit use		3.00	lb./SF				
Grit blast with Water injection - Water use		0.12	gal/SF				
Vacuum Blast grit use rate		1.00	lb./SF	This is the grit consumption rate for the project NOT the amount needed to clean each SF. If new grit is specified increase this amount, otherwise 1 lb./SF is a reasonable average consumption.			
Paint usage rate		400	SF/gal	The ideal spreading rate at the specified WFT			
Fuel usage rate		12	gal/day	For all equipment at the jobsite			

Figure 8. Example Material Cost Factors and Usage Rates. Blue cells are adjustable by the Cost Model User.

SUMMARY

Use this documentation while experimenting with using the Cost Model Spreadsheet. The basic spreadsheet pages used are the first three of the Cost Model. The last spreadsheet contains blue colored cells that allow for a more customized cost analysis by the user.