# Cost Model for Offshore Piping Installation

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## ABSTRACT

Research in the Construction Management Research Unit (CMRU) at Dundee University revealed that 20% of those items, whose value is greater than the mean of the total bill, represents 80% of the total bill value. Therefore, only one fifth of the total present jobcard items are needed, to build an efficient cost model of the construction process. The construction project could still be managed and controlled effectively by using this 80/20 rule, sometimes known as the principle of cost-significance. Using this philosophy it has been possible to develop a simple resource-based cost model for estimating and control for offshore piping installation based on the principle of resource-significant items. Resource-significant items (rsi's) are defined as those taks whose manhours are greater than or equal to the mean manhours of similar tasks within one jobcard. They generally account for 33% of the total number of items and contribute 81% of the jobcard value (excluding fixed items like hydrotests and leak tests and permanent and temporary support). The resource-based cost model comprises a few resource-significant work packages (rswps) sometimes known as the monitoring model. The resource-significant work packages (rswps) represent distinct offshore site activities, which are easily identifiable and measurable. They can predict the total manhours in the jobcard to an average accuracy ranging from ±1.27% to ±2.35%.

## INTRODUCTION

### General

Estimating is still more an art than a science. According to Asif (1988) cost estimaing is a process of predicting the most likely cost of a construction project. Fine (1968) refers to it as guesses of future costs. Some estimates may be too conservative and other too optimistic. In reality, however, many things do not turn out as planned. It is the inherent nature of estimates that inevitably they will be wrong. Zakieh (1991) states that a cost estimate is never 100% accurate and its accuracy can only be expressed by the degree to which estimated costs are distributed about the actual costs. In spite of this, estimating is still an essential process in nearly all construction companies. Bids and contracts are based upon estimates and company profitability is linked to estimating skill (Fine and Hackemer, 1970).

Traditional methods of jobcard estimating involve the meticulous taking-off of individual activities and quantities from drawings and work packs onto the jobcards. Manhours rate is then assigned to each activity described in the jobcards from the "Norms" tables available. The total direct manhours estimated are used for the purpose of monitoring the productivity levels of construction work off shore with a view to improving them in the future.

The process can be very time consuming due to the tedious use of the "Norms" tables. Where there is no "Norms" available, guesswork is often used for estimation. Different "Norms" are often used for different projects resulting in inconsistency in the estimating procedures. Furthermore, feedback of performance data from offshore sites does not correspond with the detail estimating of jobcards, thus making comparison between actual and estimated figures difficult, hence impeding the control process.

At present there is no consistency in the estimating procedure for offshore contractors because different "Norms" tables are used for different projects. Where there are no "Norms"

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tables available, guesswork is often used for estimation. Initially, work for this research started off by analyzing and studying the data from several projects, which consisted of tens of jobcards and drawings for the piping discipline. An initial model was developed from this analysis. Due to the inconsistency of using different "Norms", the estimators preparing the jobcards make consistent errors. It was felt that such an approach was neither logical nor ideal.

As a result, an alternative, more rational approach was adopted based on the principle of cost-significant items developed by the Construction management research Unit (CMRU) of the University of Dundee (Abed, 1991; Asif, 1988; Mair, 1990; Saket, 1986; Shareef, 1981). By concentrating on "significant work elements" and consistent "Norms" tables, it is hoped that a simpler estimating method and monitoring model can be derived. This model will hopefully provide feedback from the offshore site to enable management to control any productivity and cost variances by simply concentrating on the monitoring of the significant work elements.

***Objective***

Traditionally, jobcards manhours estimate are built up by identifying and listing all tasks or activities from the drawings or work pack onto the jobcards. The manhour rate taken to complete these individual activities or tasks is extracted by reference to the tedious and time consuming "Norms" tables. However, to control a project, we need only be interested in those items or activities whose variances would have a significant effect on the project outcome. If such significant items can be established, then estimating and monitoring a construction project need only to be based on these significant items.

The objective of this paper is to identify and isolate resource significant items (rsi's) from the jobcards of 'Norms" tables and use these to design a simple resource-based cost model for piping installation on which a computerized control system could be based.

***Resource Significant Items***

Based on the principle of cost-significant items, 20% of the items in a bill of quantities (boqs) are supposed to account for 80% of the value (Abed, 1991; Asif, 1988; Harmer, 1983; Mair, 1990; Saket, 1986; Shareef, 1981). Shereef (1981) showed that these cost-significant items are quite simply those whose value is greater than or equal to the mean value of all measured items, the mean measured item value being the total bill value divided by the total number of measured items. Zakieh (1991) demonstrated that the same laws could be applied to quantities. Since jobcards items are expressed in manhour estimates, it seems possible that the principle of resource-significant items could be applied to develop a resource-based cost model. This will involve the identification of the resource-significant items (rsi's) from the jobcards. Resource-significant items (rsi's) can then be simply defined as those tasks whose manhours are greater than or equal to the mean manhours of similar tasks within a jobcards. The procedure for the development of the model is summarized as follows:

1. Identify the significant-manhour tasks using the philosophy of resource significance;
2. Identify any consistency among other tasks together to form a single task such as field fit weld (FFW) which will always involve the following tasks:

| | Task | Norm Manhours |
|---|---|---|
| i. | – cutting | a |
| ii. | – weld preparation | b |
| iii. | – position (set butt) | c |
| iv. | – pre-heat | d |
| v. | – weld | e |

Spools of pipe with the same nominal pipe size, same schedule and under the same pressure will have the same manhours required for each of the above tasks. Therefore, these tasks can be combined together to form a single significant task known as field fit weld. It will then have a single manhour figure made up as follows:

$$\text{Field Fit Weld} = a+b+c+d+e \quad (1)$$

3. Identify separately hydrotests and leak tests;
4. Identify separately temporary and permanent support;
5. Calculate the manhours of the significant tasks as a percentage of the total manhours of each jobcard excludiong the tasks identified in stage 3 and stage 4;
6. Derive a model factor, which is the average of the figures obtained in stage 5.

### *Assumptions and Explanations of the Procedure*

1. "Fire-watch" which involves all flame and spark-producing work has no "Norms" at the moment and is estimated separately by the estimator using "guesswork". It is however required for all field fit weld and a lump sum estimate will be added to the field fit weld figure in the development of the model. The "Fire watch" figure analyzed from the jobcard is assumed to be proportional to the number of field fit welds in each jobcard.
2. Since hydrotests and leak tests are consistently allocated 20 manhours and 4 manhours, respectively, they are excluded from the resource- significant items and are separately identified. Temporary and permanent support manhour tasks are excluded and identified separately as they do not occur consistently.

This paper explains the above procedure in detail and presents the resulting model.

## Development of the Model

### *Analysis of Data*

The data analyzed for the development of the model involved about 10 jobcards and 15 drawings. In general, piping installation estimates are affected by:

- The diameter of the pipe (or pipe size).
- The thickness of the pipe (Schedule or class).
- The pressure rating of the pipe; and the pipe material, for example whether carbon steel or stainless steel is used.

A change in any of the above will lead to a different result or output rate; therefore, it was important to select pipe work of similar nature for the development of the model. From the analysis of the data, it was decided to select drawings describing general pipe work for spools of the following nature:

| | | |
|---|---|---|
| Size | : | 3" |
| Schedule | : | 80 |
| Pressure | : | Medium |
| Type of pipe | : | Carbon steel |

### *Identification of Resource-Significant Items*

The procedure for the development of the model summarized earlier in steps (1) – (6) was applied to all available jobcards and drawings of the same pipe size of 3", schedule 80 and with the same medium pressure. By inspection of the jobcards, a large number of similar activities in the jobcard could be classified under three main task headings:

- Handling of spool.
- Field fit weld (FFW); and
- Bolt-up. By applying the principle of rsi's defined earlier, the rsi's for each jobcard can be determined. This can be illustrated by using jobcard 1 (Drawings 15084) in Table (1) as an example.

From Table (1), we can categorize jobcard items into broad groups:

1. Main items, relating to rsi's such as the field fit weld (FFW), handling of spools and bolt-ups.
2. Ancillary items, relating to activities involving items such as blind, valves, flanges and spectacle blinds; and
3. Fixed items, relating to hydrotest; and leak test, including temporary and permanent support only if they are applicable.

Typically the rsi's identified from the jobcards, consist of approximately 33% of the total items in each jobcard excluding the fixed items relating to hydrotest and leak tests, and temporary and permanent support. This can be illustrated by using activities shown in Table (1). Similar analysis was conducted for other jobcards as shown in Table (2), which summarize the resource-significant items expressed in percentage terms of the total manhours in each jobcard. It can be seen from Table (2), that on average such rsi's account for approximately 81% of the total manhours in each jobcard (excluding the fixed items manhours relating to hydrotest and leak tests and permanent and temporary support).

### *The Model Factor*

The model factor represent the constant proportion of the rsi's manhours to the total manhours in the jobcard. As stated in the procedure in the development of the model the 'total manhours' referred to here in the calculation of the model factor do not include the followings:

i. The manhours for hydrates and leak test; and
ii. The manhours for temporary and permanent support.

Therefore, the ris's manhour expressed as a percentage of the 'total manhours' in the jobcard excluding the manhours in (i) and (ii) above is called the model factor or the resource model factor (RMF). This is calculated as approximately equal to 0.81 (Table 2).

## Grouping Resource Significant Items into Resource-Significant Work Packages

### *Resource-Significant Work packages (RSWPS)*

Having established the model factor, it is now possible to develop a simple model by concentrating on the minimum amount of information required. From analysis of the drawings and jobcards of the project, it was found that the manhour tasks could be categorized in such a way that roughly the same resource-significant items occurred within any one category. In addition, many resource significant items were so similar that they could be combined together into resource-significant work packages, which correspond closely with offshore site operation. For instance, fire watch, which has no Norms, could be included in the FFW instead of being identified separately by guesswork at the moment. For a pipe size 3" (schedule 80) fire watch which involves all spark and flame producing work, is taken to include the following:

| | Task | Norm Manhours |
|---|---|---|
| 1. | – cutting | 0.21 |
| 2. | – weld preparation | 0.16 |
| 3. | – pre-heat | 0.60 |
| 4. | – weld | 1.40 |
| **Total Manhours** | | **2.37** |

Handling is involved when spools of pipe are transported from place to place. Therefore, transportation could also be included as a resource-significant work package by using the same manhours 'Norms' as handling.

Another method of rationalization is to use the 'Norms' tables to convert all units of measurement of the resource-significant items into manhours per unit of measurement for example the manhours per joint of bolt-up required for a 3" pipe size (schedule 80) with medium pressure is 0.8 manhour.

Using rationalizations like these, it is now possible to establish a proposed standard procedure for construction work offshore in order to illustrate how the standard resource-significant work packages can be formed to develop the model. Using the manhours from the 'Norms' tables available, the proposed standard procedure for construction work offshore based on pipe size 3" (schedule 80) and thickness < 19 mm is illustrated in Figure (1).

The following assumptions for the procedure shown in Fig. (1) are made:

1. The length of the pipe is 1 meter.
2. A single field fit weld (FFW).
3. 1 spool is used.
4. Thickness of the pipe < 19 mm and
5. Transportation of pipe involves the handling of pipe, therefore the same 'Norm' for handling is used.

The column for trade indicates the different types of workers involved such as:

1. Pipe fitter (PF).
2. Rigger (RG).
3. Welder (W).
4. Instrument Technician (IT).

Vendor in the trade column indicates works carried out by other parties to the contract. The rswps manhours are then established as follows:

1. Handling which is affected by the lngth per meter of pipe involves the following tasks:

| | Task | Trade | Norm Manhours |
|---|---|---|---|
| i. | Trial fit spool | PF | 1.57 |
| ii. | Remove spools | PF | 1.57 |
| iii. | Erect | PF | 1.57 |
| **Total Manhours for Handling One Meter of Pipe** | | | **4.71** |

2. Field Fit Weld which is affected by the number of FFWs involves the following tasks:

| | Task | Trade | Norm Manhours |
|---|---|---|---|
| i. | Cutting | PF | 0.21 |
| ii. | Weld preparation | PF | 0.16 |
| iii. | Position (set butt) | PF | 1.60 |
| iv. | Pre-heat | PF | 0.60 |
| v. | Weld | W | 1.40 |
| vi. | Fire watch | RG | 2.37 |
| **Total Manhours for One FFW** | | | **6.34** |

Note: There are no "norms" for "set butt" and "fire watch". Set butt is provided by the estimator as an approximate guess "fire watch" includes all other manhours except "set butt".

3. Bolt-up which is affected by the number of joints involves PF trade and it will need 0.8 manhours.
4. Transportation of pipe which is affected by the number of spools involves the following tasks:

| | Task | Trade | Norm Manhours |
|---|---|---|---|
| i. | Transport spools from storage to workforce | RG | 1.57 |
| ii. | Transport to fabrication (ffw)shop | RG | 1.57 |
| iii. | Transport to non-destructive testing | RG | 1.57 |
| iv. | Transport to hydrotest | RG | 1.57 |
| v. | Transport spool to workforce | RG | 1.57 |
| **Total Manhours for One Spool** | | | **7.85** |

Hydrates, leak test and calibrate gauge and recorder can be combined together for a total test figure of 24 manhours. This is separately added to the above rswps.

### *Defining the Model*

It was concluded from the previous analysis and from Table (2) that the resource significant work packages are handling, FFW and bolt up tasks. These tasks contribute 81% of the total manhours in the jobcard excluding hydrotest and other tests, and permanent support (if applicable). Using these findings the model can therefore be defined by following the steps below.

a. From the drawing, the total length of the pipe (L) is taken. The total manhours for handing is computed as: L x 4.71.

b. Count the number of FFW's (W). The total manhours for FFW's is then computed as W x 6.34.

c. Count the number of joints (J). The total manhours for joint is then computed as: J x 0.80.

d. Count the number of spool (S). The total manhours for transportation is then computed as: S x 7.85.

e. The sum of (a), (b), (c) and (d) is divided by 0.81.

f. Add a total of 24 manhours for hydrotests and leak tests.

g. Add the manhours for temporary and permanent support (if applicable).

The formula for the model can be expressed as follows:

$$H = [(W \times 6.34) + (L \times 4.71) + (J \times 0.80) + (S \times 7.85)] / 0.81 \quad (2)$$

+ (24 manhours for hydrotests and other tests + temporary and permanent support (if applicable)).

Where H = Number of manhours.
W = No. of FFW's.
L = Length of the pipe.
J = No. of joints.
S = No. of spools.

***Statistical Analysis***

The model developed so far applies for a given pipe diameter and given pipe schedule. The next step in the development of the model was to find a way of developing a single model which could be applied to all pipes and schedules. Essentially, the existing model has three components; welding, handing and transportation, and bolt-up. It was hypothesized that the time required for welding would be proportional to the volume of weld metal required. This is a function of diameter and thickness of the pipe. It was also hypothesized that handling and transportation hours would be a function of the weight of the pipe per unit length. This is also proportional to the diameter and thickness.

Finally, it was hypothesized that the time required to carry out the bolt-up operation was a function of the load to be carried by the pipe, this too is reflected by the diameter and thickness of the pipe. It was therefore decided to carry out a statistical analysis of the relationship between the manhours required for each element of the model and the value of the diameter multiplied by the thickness (d x t) for pipes of different and thickness.

Table (3) shows the relationship of the rswp's manhours to diameter x thickness of pipe for a selected schedule 80 pipe. The manhours rate for the rswp's is obtained by applying the rate from the 'Norms' tables to the number of activities in each rswp's. For example, handling typically always consists of trial fit the spool of pipe, remove the spool of pipe, and erect the spool of pipe. Each of the tasks under handling utilizes the same handling 'Norms' of 1.57 manhours. These are then dded to form a single manhour rate for the handling rswp. The computation for pipe size 3" (schedule 80) was shown in section 3.1. The same computation could be done for pipe with different diameter and thickness.

Linear regression analysis was then conducted on each of the rswp's manhours relationship against the diameter (d) multiplied by the thickness (t) of the pipe for schedule 80. Figure (2) illustrates the rswp's manhours linear relationship to (d x t).

The statistics from the Regression Analysis shows a confidence level of greater than 95% that the slope of the graph is significantly different from zero for all the rswp's. This indicates that there is a very strong relationship between the manhours of the rswp's and the diameter times thickness of the pipe. The regression equation gives a good fit of the data with an R-squared value greater than 98%. The results of the best-fit-equation for each of the rswp's are presented in Table (4).

The model for schedule 80 can be expressed as follows:

$$H = W\,[2.40 + 3.29\,(dt)] + L\,[3.96 + 0.95\,(dt)] + J\,[0.87 + 0.2\,(dt)] + S\,[6.60 + 1.58\,(dt)] / 0.81 \quad (3)$$

+ (24 manhours for hydrotests and other tests)
+ Temporary and permanent support (if applicable)

Where H = Number of manhours.
W = No. of FFW's.
L = Length of the pipe.
J = No. of joints.
S = No. of spools.
d = Diameter of pipe.
t = Thickness of pipe.

On the premise that the final model is obtained for pipe of schedule 80, further regression analysis can be carried out to confirm the evidence on pipe of a different schedule (schedule 40 in this case). Figure (3) shows the linear relationship of rswp's manhours against the diameter times thickness.

The results for the regression analysis are presented in Table (5).

The model for schedule 40 can be expressed as follows:

H =W [2.26 + 3.63 (dt)] +L [2.66 +1.28 (dt)] + (4)
J [0.71 + 0.49 (dt)] + S [4.44 + 2.13 (dt)] / 0.81
+ (24 manhours for hydrotests and other tests)
+ Temporary and permanent support (if applicable)).

By combining the data for schedule 80 and schedule 40 pipe, further regression analysis is carried out to confirm whether a single model can be produced for all schedules of pipe. Fig. (4) shows the linear relationship of rswp's manhours against the diameter * thickness for the combined pipe schedules 80 and 40.

The results for the regression analysis are presented in Table (6).

The final single model for pipe of different schedules can be expressed as follows:

H = W[2.78 +3.33 (dt)] +L [3.57 +1.02 (dt)] + (5)
J [1.09 + 0.28 (dt)] + S [5.95 + 1.69 (dt)] / 0.81
+ (24 manhours for hydrotests and other tests)
+ Temporary and permanent support (if applicable).

Having obtained the final model, we can now consider the possibility of determining from the model the number of manhours required for tradesman's work. For example the number of manhours estimated for the pipe fitter, welder, rigger, etc.

*Tradesman Estimated Manhours*

From the rswps established from the proposed standard procedure, we can determine the percentage manhour requirement of each trade. The analysis of the breakdown is given in Fig. (5).

We can therefore use the percentage of tradesman manhours calculated to determine from the variables in the final model the number of manhours required in each trade. That is, for each rswp's operation, the number of hours for each tradesman is extracted by applying the percentage to the manhours determined by each individual rswp's equation. This figure is then multiplied by each rswp's variable to determine the tradesman manhours in each rswp. The manhours calculated for each trade are then added together to form the total hours for each tradesman. Assuming the number of manhours predicted by each rswp's operation is H, then the tradesman manhours can be calculated as shown in Table (7).

H = The number of manhours determined by each rswp's equation.
W = No. of FFW's.
L = Length of the pipe.
J = No. of joints.
S = No. of spools.

The total tradesman manhours for pipefitters (X), riggers (Y) and welders (Z) can be rewritten as follows:

X = 0.41 W [2.78 + 3.33 (dt)] + (6)
[3.57 + 1.02 (dt)] + J[1.09 + 0.28 (dt)]
Y = 0.37 W [2.78 + 3.33 (dt)] + S [5.95 + 1.69 (dt)]
Z = 0.22 W [2.78 + 3.33 (dt)]

**Definitions of Accuracy**

***In-Accuracy of A Model Estimate***

The accuracy of a single model estimate i defined as the percentage difference between th predicted value made by a resource-significant cos model and the actual jobcard value (Asif, 1988 Zakieh, 1991) Thus:

In-Accuracy of a model estimate, Ac = (EV-AV)/ AV * 100(%) (7

Where: EV = Estimated value using the model.
AV = Actual value using traditional methods.

The closer the value of Ac to zero the mor accurate the prediction.

***Mean In-Accuracy of A Model***

For a series of estimates the average value of Ac represents the means accuracy of the model.

Mean Model In-Accuracy, AC = Average value of Ac.

When the mean model in-accuracy is equal to zero, it indicates that the model does no consistently under - or over - estimate the actual jobcard figures.

The total manhours of the rswps for each jobcard were divided by the resource model factor (RMF) of 0.81 to obtain the total.

### Model Manhour Estimate Versus Conventional Jobcard Estimate

From Table (2) the following information was obtained from jobcard 1 and drawings 15084.

1. The number of FFW (W) is 3.
2. The length of pipe (L) is 4.58 meter.
3. The number of spools (S) of pipe is 4.
4. Since bolt-up depends on the number of joints and in turn depends on the number of FFW's, the number of joints here is assumed to be 3.

By inputting the above data into the final model, the breakdown of the tradesman manhours for a 3" pipe with schedule 80 can be predicted. This is illustrated in Table (8).

The total manhours of the rswps for each jobcard were divided by the resource model factor (RMF) of 0.81 to obtain the total jobcard manhour estimate.

This is computed as follows:

| | m/hrs |
|---|---|
| 1. Total rswp manhour | = 71.83 |
| 2. Divide by resource model factor | = 0.81 |
| 3. Total manhour estimate for jobcard | = 88.68 |
| 4. Add hydrotests and leak tests | = 24.00 |
| Model Manhour Estimate | **112.68** |

By using the same method of computation for all the jobcards, the model manhours estimate for the existing jobcards can be obtained.

In order to compare the model manhour estimates with existing jobcard figures produced by the conventional method, the jobcards have to be re-estimated using the proposed standard procedure used in the development of the model. By re-estimating all the existing jobcards, the standard jobcards re-estimated figures could be obtained for comparison against the model manhour estimates. The results are shown in Table (9).

Whilst the model in its simplest form consists of only a small proportion of the jobcard tasks, it is capable of predicting the total manhour per jobcard to an average accuracy ranging from ±1.27% to ±2.35%. The achieved accuracy is shown in Table (9). The model will also reduce the estimating time of the estimators by more than 50%.

## CONCLUSION

By using the philosophy of resource-significant items, an alternative simplified standard procedure of estimating can be established to develop a simple model for predicting the total manhours of pipework installation offshore. The model is capable of predicting to an average in-accuracy ranging from ±1.27% to ±2.35% of the jobcard figure and can reduce the estimating time of the estimators by more than 50%.

This resource-based cost model is also capable of predicting the breakdown of manhours for each trade by applying the standard percentage of each trade determined from the rswps. Such a simple model could be computerized and used as a basis for estimating, planning and cost control for piping installation offshore.

## NOTATION

| Abbreviation | Meaning |
|---|---|
| a- | cutting |
| b- | weld preparation |
| c- | position (set butt) |
| d- | pre-heat |
| e- | weld |
| H | Number of manhours |
| W | No. of FFW's |
| L | Length of the pipe |
| J | No. of joints |
| S | No. of spools |
| d | Diameter of pipe |
| t | Thickness of pipe |
| mhrs | manhours |

**Table 1: Analysis of Jobcard 1 (Drawings 15084).**

| Items | Handling (mhrs) | FFW (mhrs) | Bolt-Up (mhrs) | Temp & permanent Support (mhrs) | Other Tasks (mhrs) | Hydro & Other Tests (mhrs) | Total ( mhrs) |
|---|---|---|---|---|---|---|---|
| 1. Install spectacle blind & ball Value | | | | | 2.00 | | |
| 2. Check alignment of spool 3", 15084-01 . mark & cut to fit weld loose Flange | 1.10 | 5.00 | | | | | |
| 3. Install spool 3" , 15084-01 | 1.10 | | 0.80 | | | | |
| 4. Install Spool 3", 150 | 2.10 | | 0.80 | | 2.00 | | |
| 5. Trial fit spool 3", 15084-03, cut to suit & weld to spools 3" 15084-02 & 04 | 4.00 | 8.90 | | | | | |
| 6. Position &weld Trunnion | | | | | 1.70 | | |
| 7. Remove values, connect spools for Hydrotesting | 7.20 | | 3.20 | | 2.40 | | |
| 8. Carry out NDT of field welds, ACC. To CE/CP/P31 | | | | | | | |
| 9. Hydrotest spools, ACC. To CE/CP/P31 | | | | | | 20.00 | |
| 10. Install spool 3" , 15084-01, 3" BALL VALUES, Spectacle blind & blind flange | 7.20 | | 4.80 | | 3.20 | | |
| 11. Inspect all mechanical joints | | | | | 20.00 | | |
| 12. Cary out leak test ACC. CE/CP/P31 | | | | | | 4.00 | |
| 13. Fire watch | | 11.00 | | | | | |
| | **22.70** | **24.90** | **9.60** | | **13.30** | **24.00** | **94.50** |

**Table 2: Summary of Resource Significant Items (RSI's) for Pipe of Size 3" and Schedule 80.**

| | | | | | Resource-Significant Items (RSI's) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Job Card | Drawings | No. Of Spools | No. Of FFW | Length (M) | Handling (mhrs) | Field FIT Weld (mhrs) | BoltUp (mhrs) | Total (mhrs) Of RSI'S | Total MHRS Of All Items Excluding Temp & Perm Support & Tests | MHRS Of RSI As% To Total (mhrs) |
| 1 | 15084 | 4 | 3 | 458 | 22.70 | 24.90 | 9.60 | 57.20 | 70.50 | 81.13 |
| 2 | 15082 | 4 | 3 | 458 | 22.7 | 24.90 | 9.60 | 57.20 | 70.50 | 81.13 |
| 3 | 15083 | 5 | 3 | 1100 | 2034 | 31.00 | 6.40 | 5774 | 73.24 | 78.84 |
| 4 | 15085 | 5 | 3 | 450 | 23.05 | 31,00 | 7.20 | 61.25 | 74.25 | 82.49 |
| | | | | | | | | | Average | 80.89 |

**Table 3: Analysis of the RSWP's Manhours Relationship to Diameter X Thickness of Pipe for Schedule 80.**

| Diameter (d) | Thickness (t) (inch) | dt (sq. inch) | FFW (mhrs) | Handling (mhrs) | Bolt-up (mhrs) | Transport (mhrs) |
|---|---|---|---|---|---|---|
| 2" | 0.218 | 0.44 | 4.64 | 3.93 | 0.70 | 6.55 |
| 3" | 0.300 | 0.90 | 6.34 | 4.71 | 0.80 | 7.85 |
| 4" | 0.337 | 1.35 | 7.80 | 5.13 | 1.20 | 8.55 |
| 6" | 0.432 | 2.59 | 10.80 | 6.30 | 1.50 | 10.50 |
| 8" | 0.500 | 4.00 | 14.30 | 7.98 | 2.10 | 13.30 |
| 10' | 0.594 | 5.94 | 21.14 | 9.84 | 2.70 | 16.40 |
| 12" | 0.688 | 8.26 | 27.70 | 12.12 | 3.40 | 20.20 |
| 14" | 0.750 | 10.50 | 37.16 | 14.37 | 3.80 | 23.95 |
| 16" | 0.844 | 13.50 | 46.70 | 16.83 | 4.40 | 28.05 |
| 18' | 0.938 | 16.80 | 59.44 | 19.29 | 4.80 | 32.15 |

**Table 4: Result of Regression Analysis on RSWP's for Pipe Schedule 80.**

| RSWP | Best Fit Equation | R-Squared value |
|---|---|---|
| 1. FFW | H= 2.40 + 3.29 (dt) | 0.99 |
| 2. Handling | H= 3.96 + 0.95 (dt) | 0.99 |
| 3. Bolt-up | H= 0.87 + 0.26 (dt) | 0.98 |
| 4. Transport | H= 6.60 + 1.58 (dt) | 0.99 |

**Table 5: Result of Regression Analysis on RSWP's for Pipe Schedule 40.**

| RSWP | Best Fit Equation | R-Squared value |
|---|---|---|
| 1. FFW | H = 2.26 + 3.63 (dt) | 0.99 |
| 2. Handling | H = 2.66 + 1.28 (dt) | 0.99 |
| 3. Bolt-up | H = 0.71 + 0.49 (dt) | 0.99 |
| 4. Transport | H = 4.44 +2.13 (dt) | 0.99 |

**Table 6: Result of Regression Analysis on RSWP's for Combined Pipe Schedule 80 and 40.**

| RSWP | Best Fit Equation | R-Squared value |
|---|---|---|
| 1. FFW | H = 2.78 + 3.33 (dt) | 0.99 |
| 2. Handling | H = 3.57 + 1.02 (dt) | 0.99 |
| 3. Bolt- Up | H = 1.09 + 0.28 (dt) | 0.90 |
| 4. Transport | H = 5.95 + 1.69 (dt) | 0.99 |

**Table 7: Computation of Tradesman Estimated Manhours.**

| RSWP | RSWP Equation | PF (mhrs) | RG (mhrs) | W (mhrs) |
|---|---|---|---|---|
| 1. FFW | H = 2.78 + 3.33 (dt) | 41%H* W | 37%H* W | 22%H*w |
| 2. Handling | H = 3.57 + 1.02 (dt) | 100%H * L | - | - |
| 3. Bolt-Up | H = 1.09 + 0.28 (dt) | 100% H * J | - | - |
| 4. Transport | H= 5.95 + 1.69 (dt) | - | 100%H * S | - |
| **TOTAL TRADESMAN MANHOUES** | | **X** | **Y** | **Z** |

**Table 8: Model Estimate of Tradesman Manhours in Jobcard.**

| RSWP | (mhrs ) Predicted By RSWP Equation | Model Variable | PF (mhrs) | RG (mhrs) | W (mhrs) | Total (mhrs) |
|---|---|---|---|---|---|---|
| FFW | 5.78 | 3 | 7.10 | 6.42 | 3.82 | 17.34 |
| Handling | 4.49 | 4.58 | 20.56 | - | - | 20.56 |
| Bolt-up | 1.35 | 3 | 4.05 | - | - | 4.05 |
| Transport | 7.47 | 4 | - | 29.88 | - | 29.88 |
| Total | | | 31.71 | 36.30 | 3.82 | 71.38 |

**Table 9: In-Accuracy of the Model Estimate.**

| Job Card No. | Drawings | No. Of Spools | No. Of Fww | Length (Meter) | JobCard Re-Estimate | Model Estimate | Model In Accuracy |
|---|---|---|---|---|---|---|---|
| 1 | 15084 | 4 | 3 | 4.58 | 111.69 | 112.68 | +.89% |
| 2 | 15082 | 4 | 3 | 4.58 | 95.69 | 96.68 | +1.03% |
| 3 | 15083 | 5 | 3 | 11.00 | 176.28 | 181.79 | +3.13% |
| 4 | 15085 | 5 | 3 | 4.50 | 118.87 | 121.46 | +2.18% |
| **Mean Model In-Accuracy** | | | | | | | **+ 1.81%** |
| **STD. Deviation Of In-Accuracy** | | | | | | | **0.54** |

| | | Trade | Manhour |
|---|---|---|---|
| 1. | Transport spools from storage to workforce (1 spool of 1 meter). | R.G | 1.57 |
| 2. | Trial fit spools (Erect).(1 meter) | PF | 1.57 |
| 3. | Remove and transport to Fabrication shop. | PF | 1.57 |
| | - remove (1 meter). | PF | 1.57 |
| | - transport (1 spool of 1 meter) | RG | 1.57 |
| 4. | Fabricate (FFW) - cutting | PF | 0.21 |
| | - weld preparation | PF | 0.16 |
| | - set-butt | PF | 1.60 |
| | - pre- heat | PF | 0.60 |
| | - weld | W | 1.40 |
| | - fire watch | RG | 2.37 |
| | | | 6.34 |
| 5. | Transport to NDT area (1 spool of 1 meter). | RG | 1.57 |
| 6. | NDT (non- destructive testing) | Vendor | - |
| 7. | Transport to Hydrotest area (1 spool of 1 meter). | R G | 1.57 |
| 8. | Hydrates (Per-test) | | 16.00 |
| 9. | Calibrate gauge and recorder | IT | 4.00 |
| 10. | Transport to workforce (1 spool of 1 meter) | RG | 1.57 |
| 11. | Erect and bolt up | | |
| | - Erect ( 1 inter x 1.57 | PF | 1.57 |
| | - Bolt-up (per joint) | PF | 0.80 |
| 12. | Leak test | PF | 4.00 |
| | Total Estimated Manhours | | 43.70 |

Fig. (1): **Standard Procedure for Construction Work Offshore Based on Pipe Size 3" (Schedule 80), (Thickness < 19 mm).**

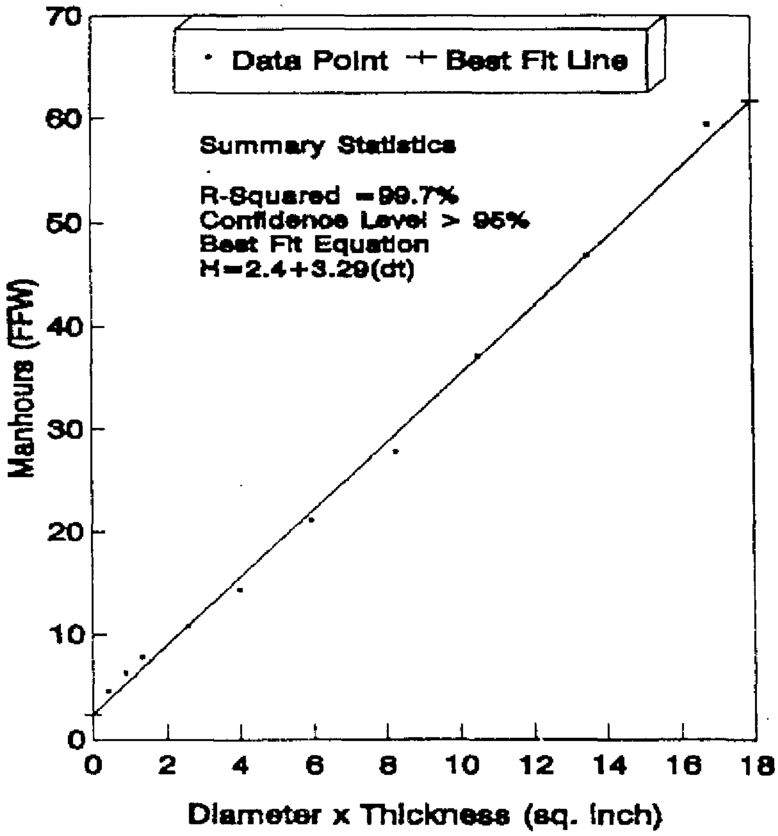


Fig. (2): Relationship of FFW Manhours Against (d x t) for Pipe Schedule 80.

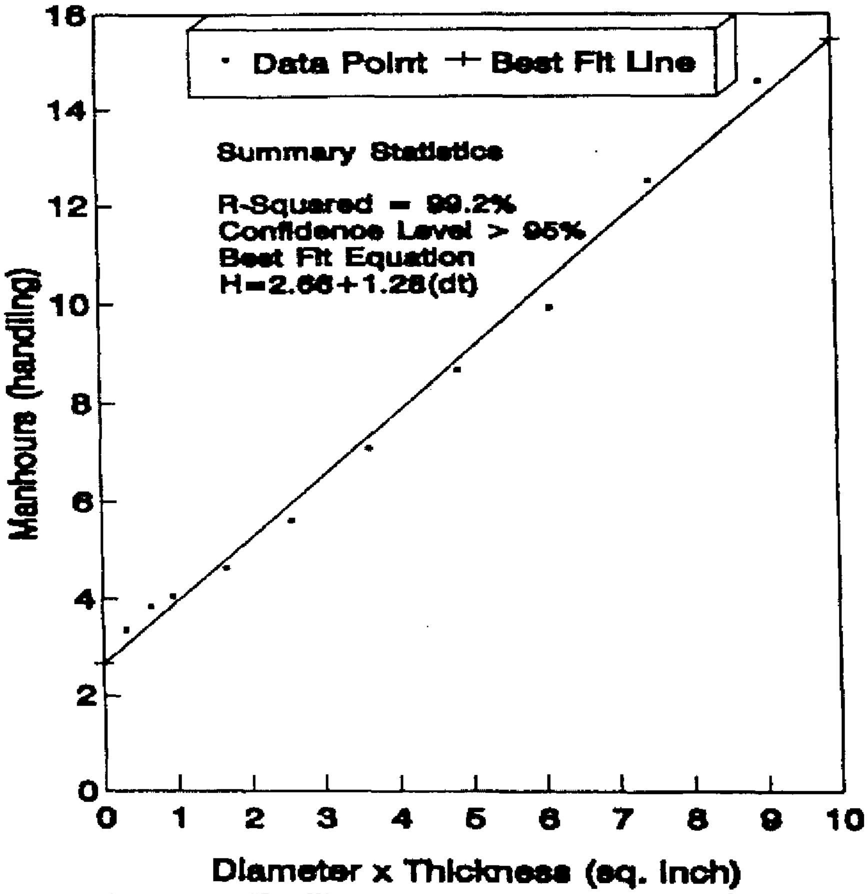


Fig. (3): Relationship of Handling Manhours Against (d x t) for Pipe Schedule 40.

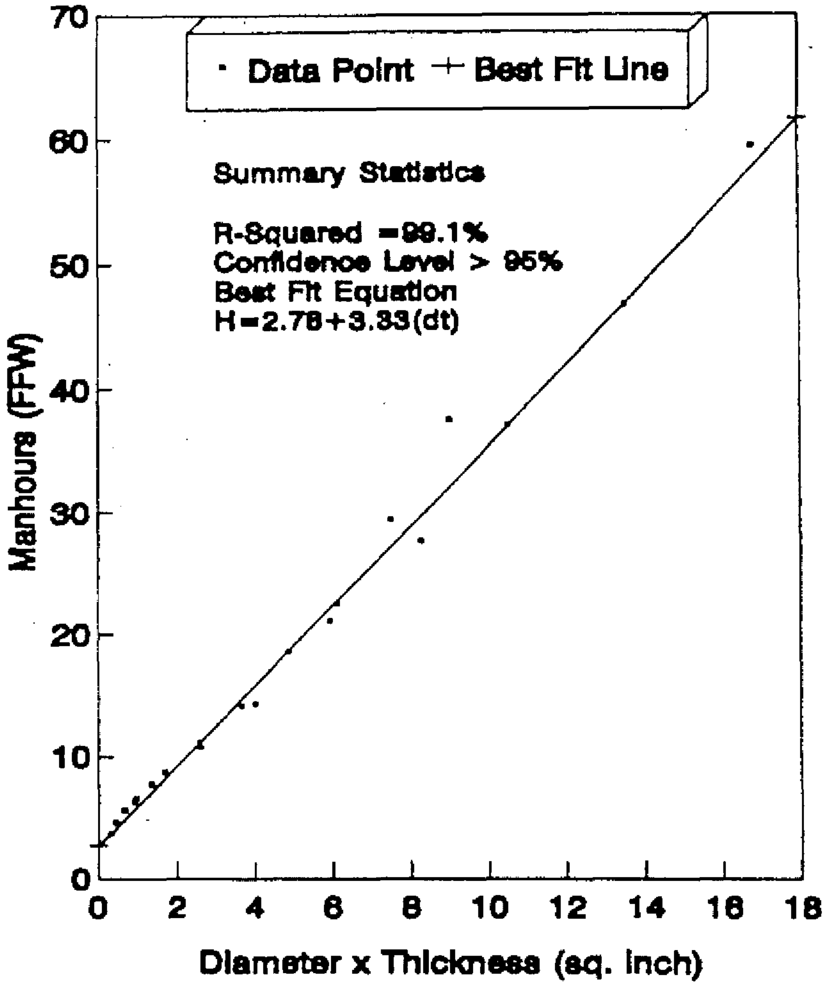


**Fig. (4): Relationship of FFW Manhours Against (dxt) for Combined Pipe Schedule 80 and 40.**

| | PF mhrs | RG Mhrs | W Mhrs | Total Mhrs |
|---|---|---|---|---|
| 1. FFW | 2.57 | 2.37 | 1.40 | 6.34 |
| (%) | 41% | 37% | 22% | 100% |
| 2. Handling | 4.71 . | - | - | 4.71 |
| (%) | 100% | - | - | 100% |
| 3. Bolt-up | 0.80 | - | - | 0.80 |
| (%) | 100% | - | - | 100% |
| 4. Trans Poration | - | 7.85 | - | 7.85 |
| (%) | - | 100% | - | 100% |

**Fig. (5): Analysis of Tradesman Manhours.**

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# نموذج تكاليف لتركيب الأنابيب في المنشآت النفطية

نبيل الضميدي *

## الملخص

ان الابحاث التي قامت بها جامعة دندي في بريطانيا بينت ان ٢٠٪ من البنود الموجودة في العقد تحتوي على ٨٠٪ من القيمة، وباستخدام هذه النظرية فإنه بإمكاننا بناء نموذج لحساب الفترة الزمنية لبطاقة العمل باستخدام ٢٠٪ من البنود. ان كافة المشاريع يمكن ان تدار وتراقب بطريقة جيدة باستخدام قانون ٨٠/٢٠، وباستخدام هذا القانون يمكن استحداث نموذج يعتمد على النشاطات الاكثر اهمية لحساب الزمن ومراقبته اثناء تركيب الانابيب في المنشآت النفطية. ان النشاط الاكثر اهمية هو النشاط الذي يحتوي على فترة زمنية اعلى من معدل الساعات اللازمة لكافة النشاطات. ان هذه النشاطات في بطاقة العمل تمثل ٣٢٪ من العدد الكلي للنشاطات وتمثل ٨١٪ من قيمة بطاقة العمل. ان نموذج حساب الفترة الزمنية يحتوي على النشاطات الاكثر اهمية ويستخدم للمراقبة اثناء التنفيذ، ويمكن لهذا النموذج ان يحسب الفترة الزمنية لبطاقة العمل بمقدار خطأ يتراوح بين ±١.٢٧٪ و ±٢.٣٥٪.

* قسم الهندسة المدنية، جامعة النجاح، نابلس، فلسطين. تاريخ استلام البحث 23/4/2000 وتاريخ قبوله 8/4/2001.