Elemental Time Studies

- Elemental time studies record times for machine activities:
  - from continuous observation of the machine
  - for a longer period of time
- Machine time is divided into elements.
- Each element:
  - has clearly recognizable starting and ending points
  - allows consistent timing in the field

Elemental Time Studies

- For example, the activities of a cable skidder are commonly broken down into the following elements:
  - Travel empty
  - Choking logs
  - Travel loaded
  - Unchoking logs
  - Deck maintenance
  - Delays

These elements make up a skidder’s work cycle.

Elemental Time Studies

- To determine the productivity of a cable skidder, we need to know:
  - time and payload in each work cycle
  - skidding distance, slope, ground conditions, and other variables associated with the cycle
- With enough data, cycle time could be predicted from one or more of these measured variables.

Elemental Time Study

Example for a Cable Skidder

- Cycle time (min.)= $9.918+0.0049SD-0.0000006SD^2+0.0338TV$
- Productivity (ft^3/PMH) $=196.771-0.096SD+0.00001SD^2+2.2425TV$

SD = average skidding distance (feet)

TV = turn volume (ft^3)

PMH = productive machine hour

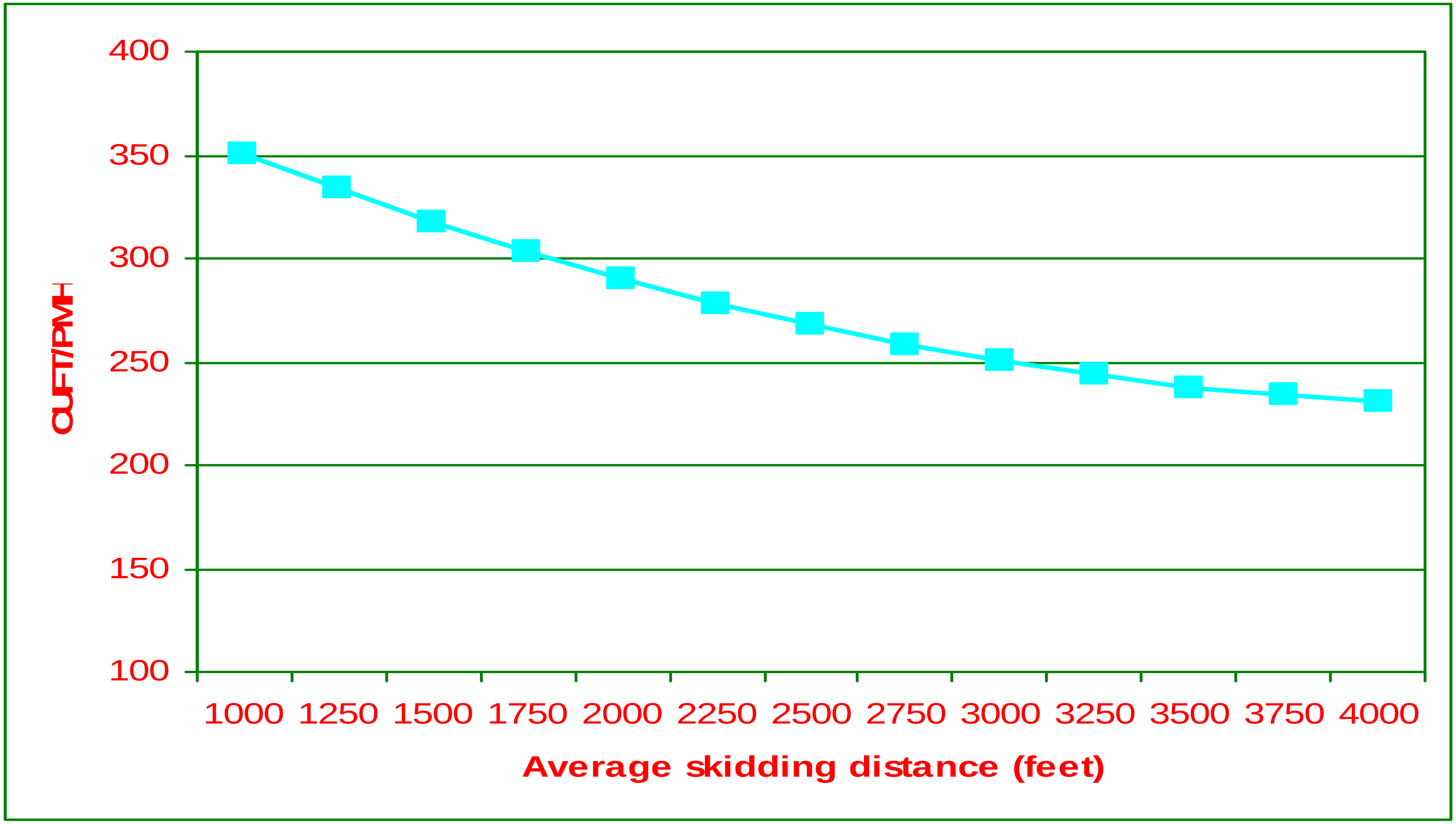
(Source: Wang et al. 2004)

Elemental Time Study

- Can be used to provide detailed and unbiased information.
- However, this method requires trained operators and can be costly and time consuming.
- Field personnel may have to work close to a machine and are placed in a dangerous position.

Productivity

For a skidder using equation developed from elemental time study



(Source: Wang et al. 2004)

Comparisons

Time Study Methods

- Each of three time study methods is a useful tool for examining logging operations.
- The selection of an appropriate time study technique depends on
  - the information you need,
  - the type of operations to be studied, and
  - the personnel and equipment available to do the task

Comparisons

Time Study Methods

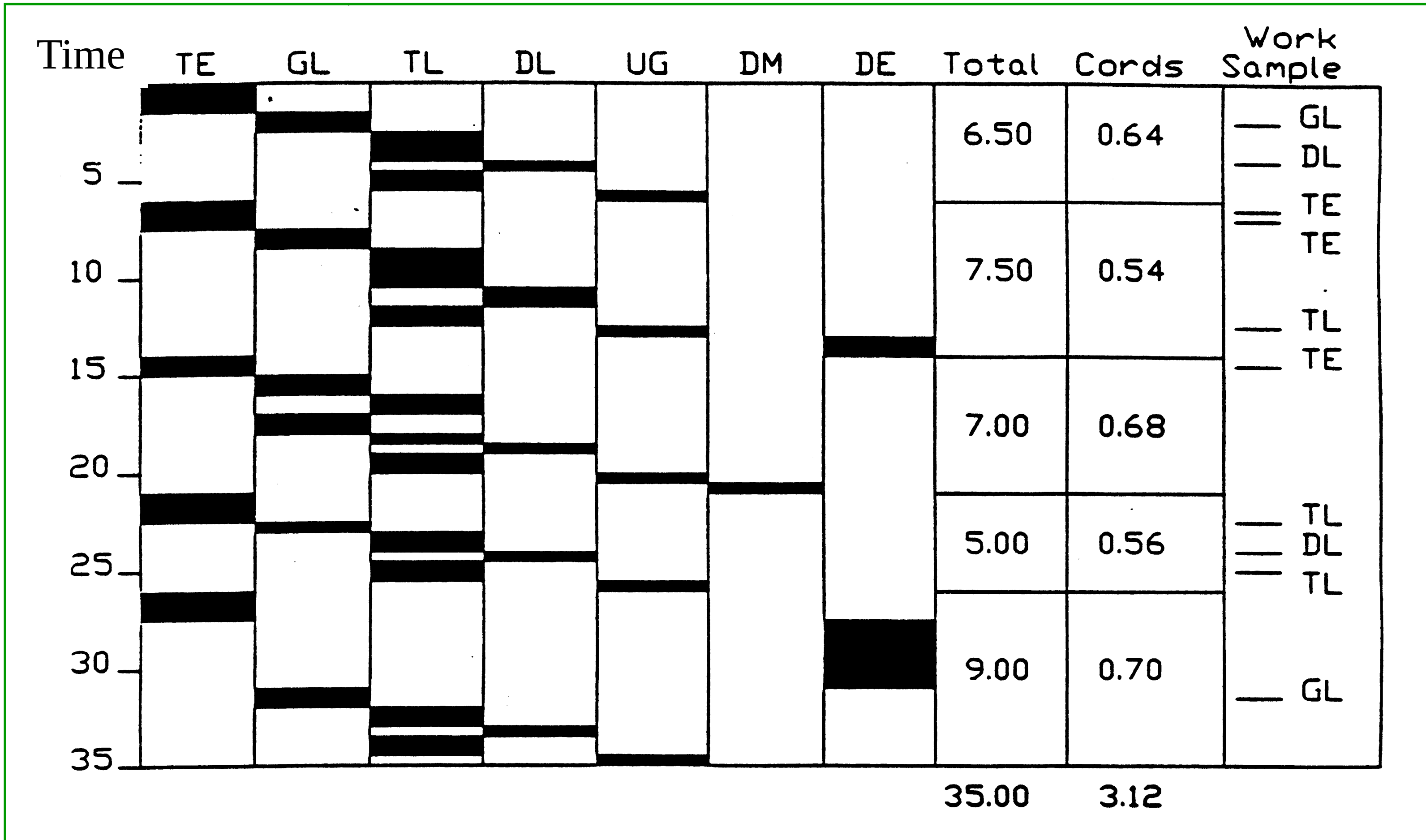
- Well planned and designed gross time studies and work samples
  - can yield a substantial amount of information
  - do not have the complexity of performing elemental time study

Comparisons

Example

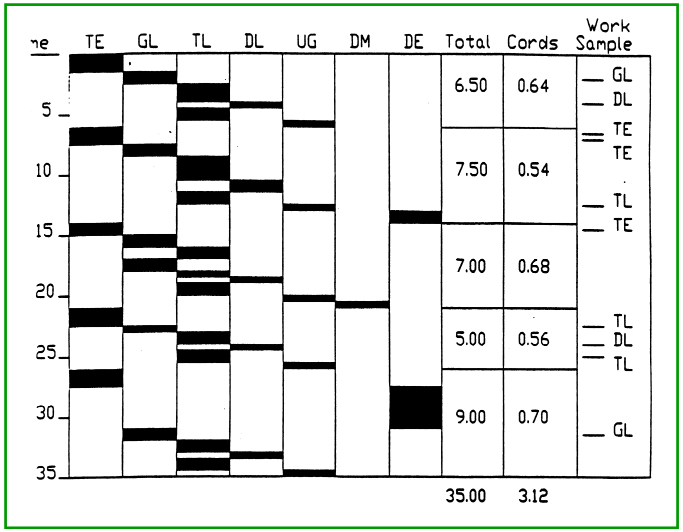
- Graphically illustrates the relationships among three time study methods.
- Covers 35 minutes of scheduled time for a grapple skidder.
- Five turns of wood are delivered to the landing during this time period.

Relationships of Three Methods



Gross Time Study

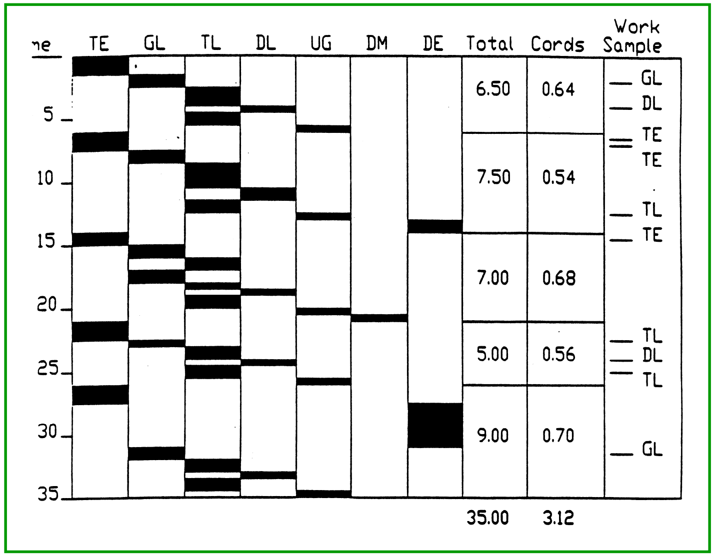
(Example)



Elapsed Time (minutes)	Payload (cords)	Productivity (Cords/PMH)
6.50	0.64	5.91
7.50	0.54	4.32
7.00	0.68	5.83
5.00	0.56	6.72
9.00	0.70	4.67
Mean=7.00	**0.62**	**5.49**

Work Sample Study

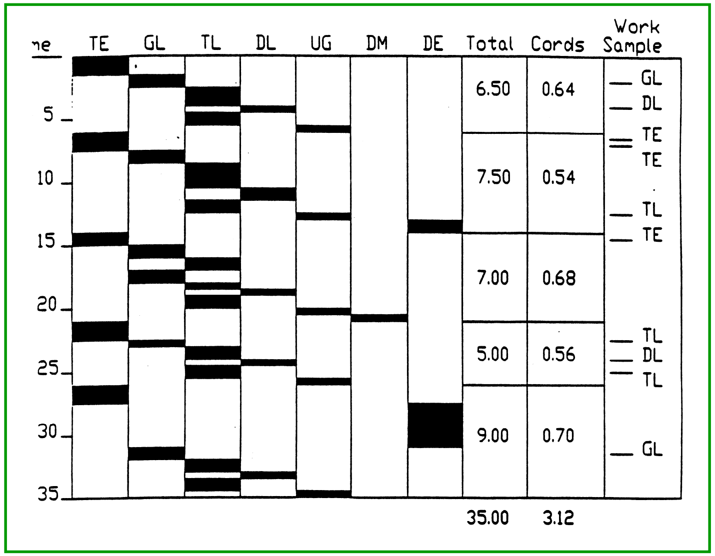
(Example)



Element	Obs	Observed %	Actual %
Travel Empty	3	30	20
Grapple Logs	2	20	16
Travel Loaded	3	30	36
Delimb Stems	2	20	9
Ungrapple Logs	0	0	7
Deck Maintenance	0	0	1
Delays	0	0	11
Total	10	100	100

Elemental Time Study

(Example)



Element	Elapsed Time (min.)	Percentage
Travel Empty	7.00	20
Grapple Logs	5.50	16
Travel Loaded	12.50	36
Delimb Stems	3.00	9
Ungrapple Logs	2.50	7
Deck Maintenance	0.50	1
Delays	4.00	11
Total	35.00	100

Regression Models

Estimating Production

- Least square regression modeling has long been an efficient, accurate method of estimating and predicting forestry data.
- It is very common to employ regression modeling to estimate tree volume based on tree diameter (DBH) and total height.

Estimating and Predicting

- Estimation involves the calculation of means and other statistics about a population from which the samples were drawn.
- Prediction on the other hand is determining what will happen in the future based on past experiences.

In tree volume example, estimate and predict?

Regression Modeling

Timber Harvesting Data

- First requires an understanding of what we want to accomplish.
- Our goal is usually to:
  - develop estimation equations
  - predict machine production rates – production per unit time under a variety of conditions

Regression Modeling

- Three types of data for each work cycle should be produced by time and production studies:
  - Times
  - Units of production
  - Work conditions

Regression Modeling

Example

- An example for feller-buncher’s productivity:
  - We would like to know how many cords per hour a FB would produce.
  - Working under a set of conditions, say trees with DBH’s from 4-22 inches.

Regression Modeling

(Times)

- Time cycle is a period of time for felling a tree or several trees.
- Times collected during elemental time studies may include such times as:
  - Move-to-tree
  - Position and cut
  - Move-to-dump
  - Dump and delays

Regression Modeling

(Production and Condition)

- The production of each cycle is the volume or weight of the tree or trees.
- The work conditions surrounding that tree are things like:
  - tree size,
  - slope, and
  - other terrain conditions

Procedures

for Regression Modeling

- A time study of feller-buncher should include several hundred cycles or trees.
- Procedures:
  - Means
  - Plotting Data
  - Fitting Models
  - Testing Fits

Data Format

DBH	Fell-Time (min.)
13	0.5963
16	0.3449
17	0.9708
14	0.6542
13	0.4615
13	0.3748
18	0.9076
14	0.9530
9	0.3259
13	0.6446
13	1.2029
13	0.3909
14	0.6322

…

Means

Example

- One way to calculate productivity is to add all times together and all volume together and divide the sums to get average volume per hour.
- Means are limited to the set of conditions observed.
- Means just give you the overall average productivity.

Plotting Data

Example

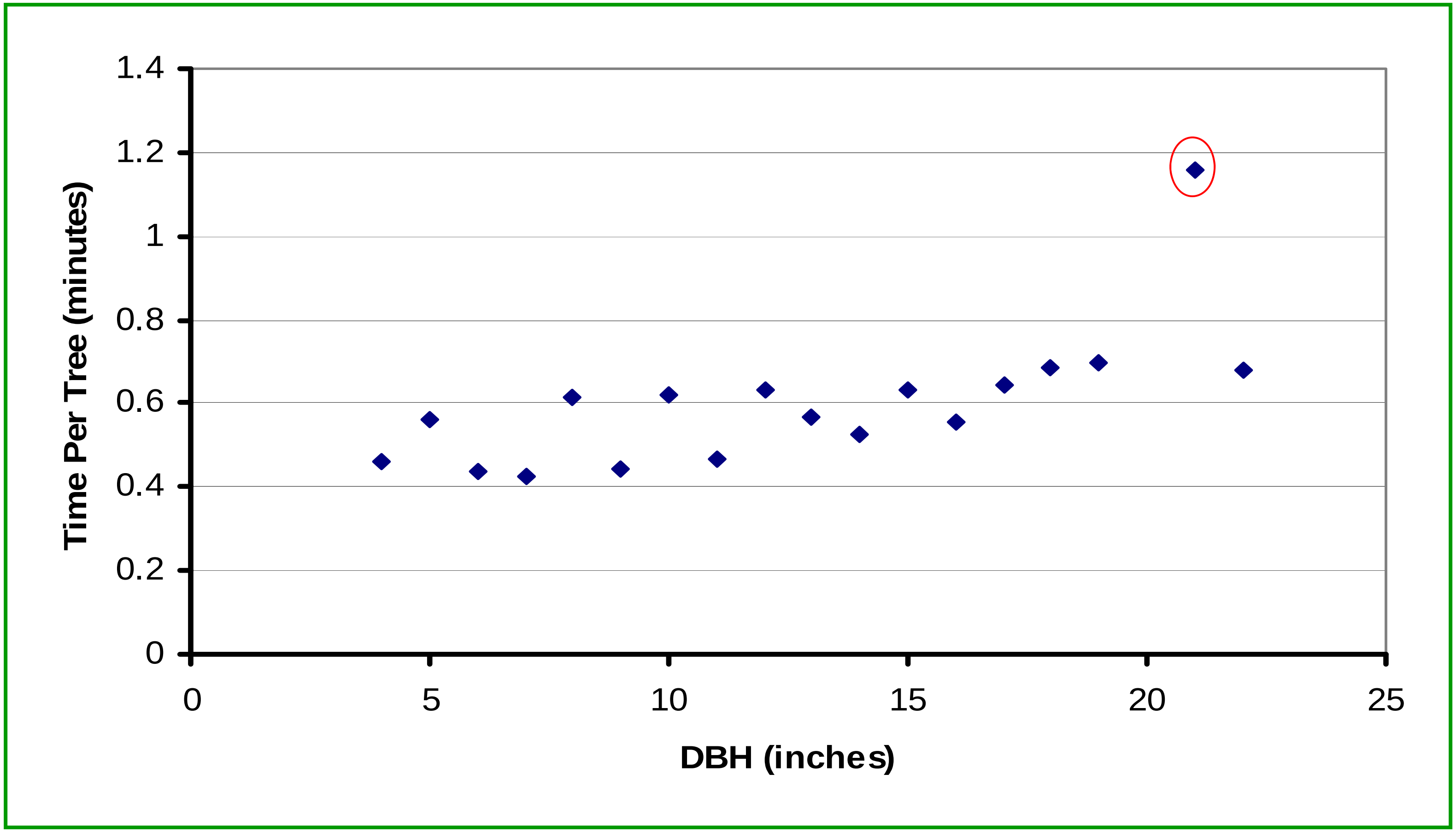
- Trees in the example are not in the same size.
  - DBH ranged from 4 to 22 inches.
  - It takes more time for a FB to cut a large tree than a small one.

Plotting Data

Example

- We calculate the average time for each-inch DBH and draw the plot.
- Now, instead of having the overall average time per tree, we have average time for each DBH class.

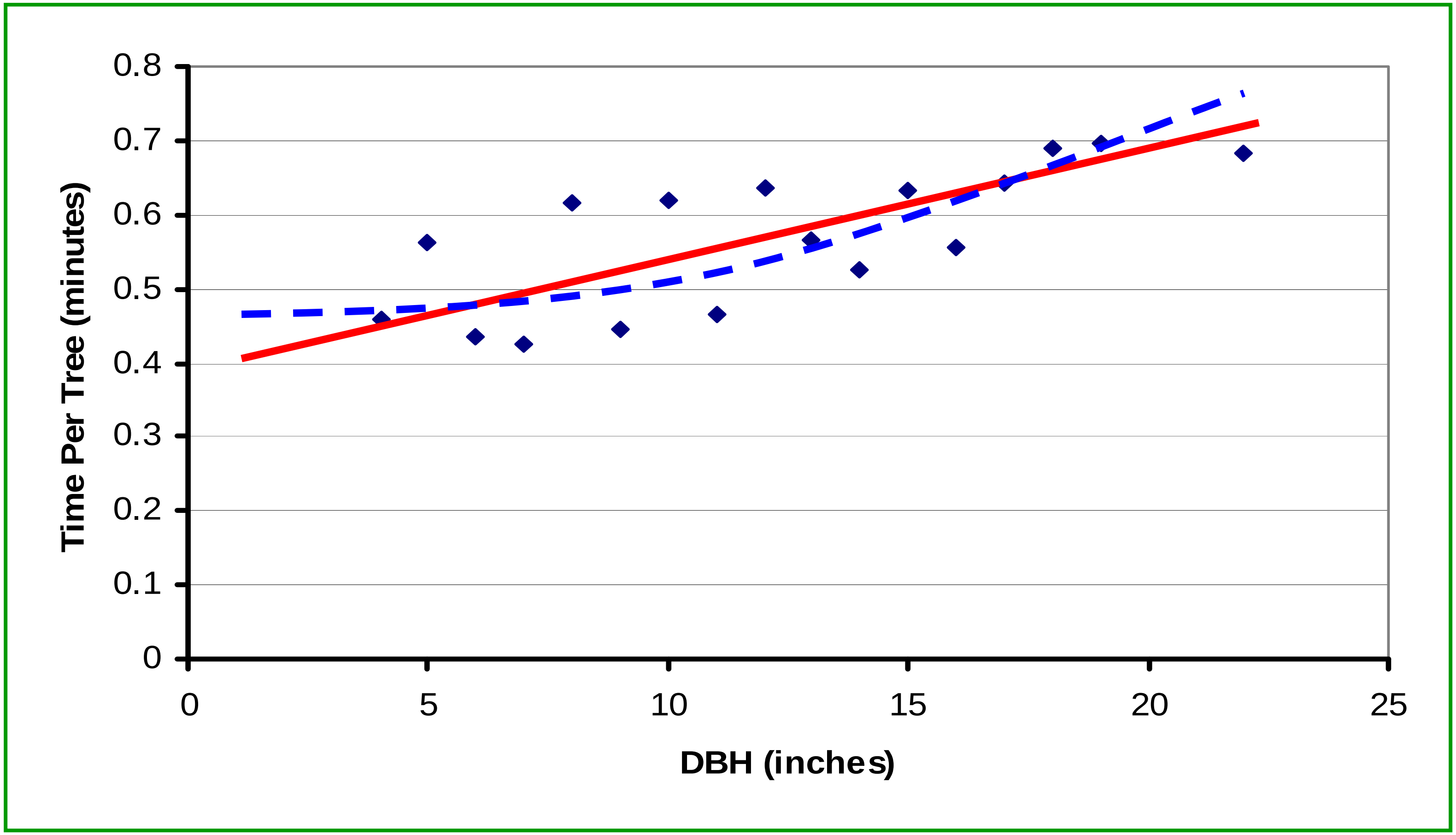
Data Plot



1.4
1.2
1
0.8
0.6
0.4
0.2
0
Time Per Tree (minutes)
0
5
10
15
20
25
DBH (inches)

Fitting the Model

Remove an outlier from the dataset.

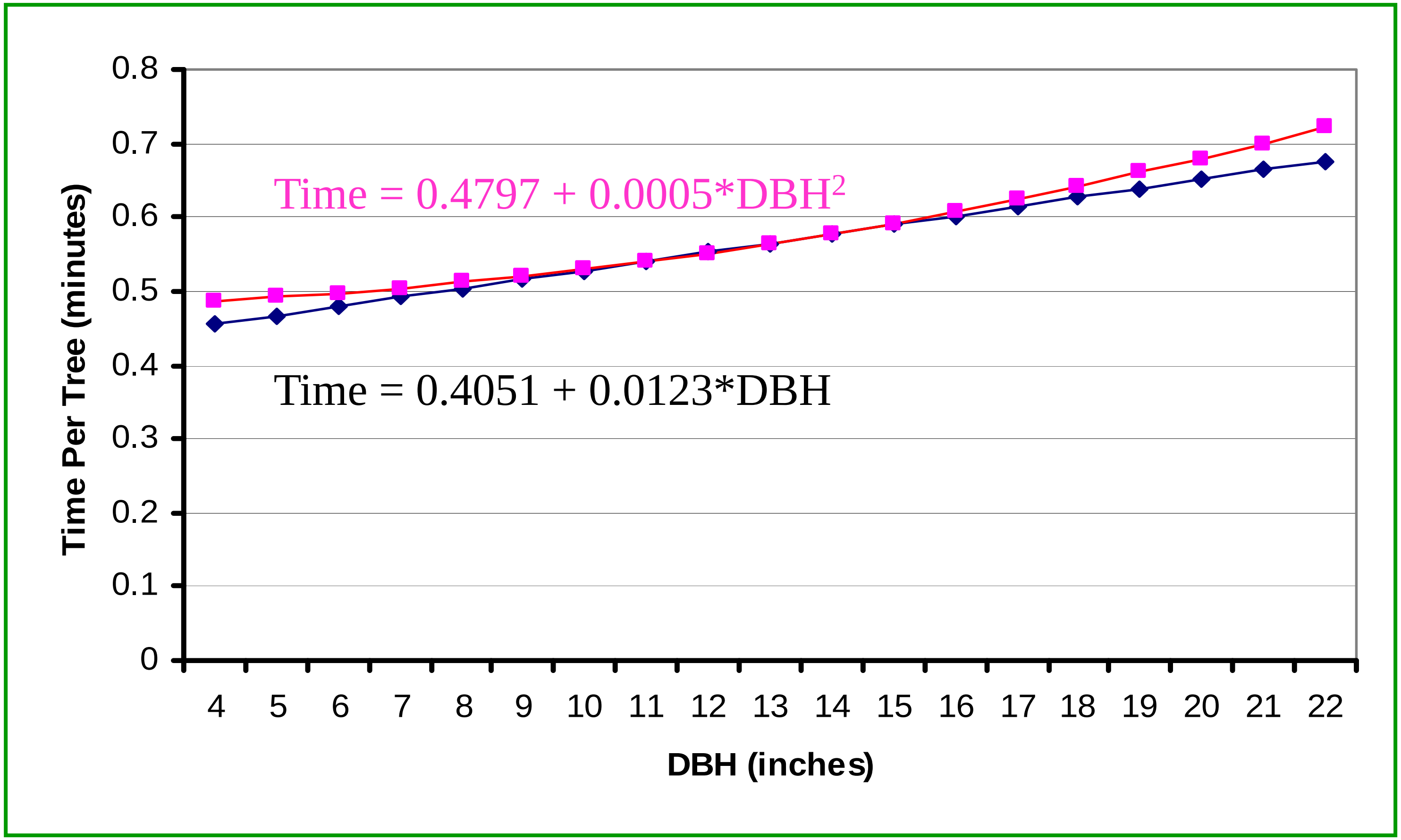


Regression Modeling Tool

SAS Programming

```
data FB;
        infile 'e:\wjx\teaching\wdsc132\labs\Bell_fb.dat';
        input DBH time;
        data FBReg; set FB;
        if time=1.4737 then delete;
        dd=dbh*dbh;
        proc reg;
        model time=dbh;
        pro reg;
        model time = dd;
        run;
```

Regression Models



Testing Fits

- Based on:
  - <u>R-Square</u> checks the correlation of independent and response variables, $0<R^2 \leq 1$.
  - <u>Root MSE</u> is the root of mean squared sum of errors. The smaller the better.
  - <u>F&P values</u> are the probabilities to check the significance of variables and the model.

Which Equations to Use?

- Where the study was conducted?
- What sizes of the trees were harvested?
- What was the range of work conditions?
- What were the terrain and weather conditions?
- What products were harvested, both species and type?
- Which machines and models were used?