12-1998

Productivity analysis for highway excavation operations

Richard L. Gatlin

To the Graduate Council:

I am submitting herewith a thesis written by Richard L. Gatlin entitled "Productivity analysis for highway excavation operations." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

J. Harold Deatherage, Major Professor

We have read this thesis and recommend its acceptance:

Edwin G. Burdette, David W. Goodpasture, Karen Chou

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Richard L. Gatlin entitled "Productivity Analysis for Highway Excavation Operations." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

J. Harold Deatherage, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and Dean of the Graduate School

PRODUCTIVITY ANALYSIS FOR HIGHWAY EXCAVATION OPERATIONS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Richard L. Gatlin
December, 1998

Acknowledgments

I would like to take this opportunity to extend my appreciation to many people whom have greatly assisted me with my graduate studies. I would first like to send my gratitude out to my thesis committee: Dr. J. Harold Deatherage, Dr. Edwin G. Burdette, Dr. David W. Goodpasture, and Dr. Karen Chou. I would like to especially thank my major professor Dr. J. Harold Deatherage for his guidance and assistance with the completion of this thesis.

I would like to thank several students for their contributions towards this research project which made this thesis possible. I would like to thank Abdul Abdulghafour, Eric Brown, Eric Bonanno, Sergay Shpanskiy, and Brent Thornton for their support and assistance with this research project.

I would also like to send my thanks to the Tennessee Department of Transportation(TDOT) and the Federal Highway Administration(FHWA). Their funding has made this research possible.

Abstract

The Tennessee Department of Transportation presently schedules contracts according to experienced based productivity rates. These productivity rates lead to inconsistent scheduling of highway construction operations. In order to improve scheduling, the Tennessee Department of Transportation funded a research project to investigate highway construction operations. The goals of this research are to develop a methodology to determine appropriate productivity rates and thus to improve task duration calculations.

This thesis concentrates on obtaining productivity rates for highway excavation operations. Field data were collected on forty-one excavation processes and various types of excavation methods. Statistical analysis indicated that highway excavation operations generally follow a lognormal distribution. After determining the appropriate distribution, a predicted productivity rate was calculated with a 95% confidence level. The methodology developed in this study will not only reduce conflicts due to scheduling but also provide TDOT with a more effective means of scheduling excavation operations and data to defend their scheduling procedures.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 BACKGROUND

For the past few decades, highway construction has not kept pace with other industries as far as improving overall productivity. In direct correlation, the cost of highway construction projects has increased considerably. The lack of improvement in productivity relates to the scheduling of jobs, a process which tends to be inconsistent. Inconsistencies in scheduling lead to higher construction costs if the scheduled time is too short and higher user costs if the scheduled time is too long.

The University of Tennessee is presently involved in a program to investigate productivity, cost, and scheduling of highway construction operations. This research is intended to provide productivity data on a broad spectrum of construction operations. Approximately twenty-three different tasks are being investigated in this research. These tasks comprise a major portion of the total time required to complete most highway construction projects. This study by The University of Tennessee is funded by the

Tennessee Department of Transportation(TDOT) and the Federal Highway Administration(FHWA).

The purpose of this research is to analyze the time duration and productivity rates of specific highway construction tasks and develop a methodology to more accurately predict time duration and evaluate delay claims on highway construction operations. The results from this study are expected to lead to a better understanding of time duration associated with highway construction operations.

1.2 TYPES OF MODELS

The Method Productivity Delay Model(MPDM)[1] was developed by James Adrian in order to allow "the average construction firm a means of measuring, predicting, and improving construction method productivity"[1]. MPDM takes a continuous sample of production cycles and notes the types of delays that occurred in the cycle and the amount of delay that was incurred. The determination of which cycles contain delays is left up to the discretion of the observer which may lead to some subjectivity in the data. From these data, one can determine the overall efficiency of the operation and show the effects that the calculated delays had on the productivity that was measured. The productivity

---

[1] Denotes Reference.

is based on an average time that may tend to be unconservative[1].

Another method for calculating productivity is queuing theory[1]. A more common model associated with queuing is the finite queuing model. The finite queuing model analyzes a finite number of resources that are served by one or more processors. The Markovian model is one of the finite queuing models. The model uses the arrival rate of the hauling units(λ) and the service rate of the processor(μ) to develop equations of state for a particular model. An example of the equations of state are as follows:

-Equations of state(one processor-three hauling units)

$$3\lambda P_o - \mu P_1 + 0 + 0 = 0$$

$$-3\lambda P_o + (\mu+2\lambda)P_1 - \mu P_2 + 0 = 0$$

$$0 - 2\lambda P_1 + (\lambda+\mu)P_2 - \mu P_3 = 0$$

$$0 + 0 - \lambda P_2 + \mu P_3 = 0$$

$$P_0 + P_1 + P_2 + P_3 = 1$$

where, Pn = probability of n number of units in the system

Once the equations of state are defined, a probability of no units(P_0) in a system can be calculated.

P_0 will allow for a means to determine the production by the following equation:

$$\text{Prod.} = L(1-P_0)\mu c \qquad (1.1)$$

in which, L = Period of time being considered
P_0 = Probability of no units in the system
μ = Average processor rate (loads/hr)
c = Capacity of cycle

The use of this model is limited to cyclic operations and operations with one or more processors.

Computer simulation[1] has been used to analyze repetitive construction operations. The software for simulating construction operations is known as CYCLONE. CYCLONE can be utilized to determine productivity. The user must model the method of operation, and must determine the time associated with each element within the operation. Since the user must determine the type of model and cycle times, CYCLONE's ability to predict future productivity is limited. However, the CYCLONE model will allow the user to enter either deterministic cycle time values or use a specific probability distribution function to determine cycle times.

1.3 PREVIOUS WORK

One recent graduate of the University of Tennessee at Knoxville has already documented the research study in his

dissertation. Abdul Abdulghafour[2] reviewed and analyzed nine of the twenty-three previously mentioned tasks. The documentation for field data collection and analysis procedures are presented in his dissertation. One difference between his study and the one presented here is the methodology used to determine cycle times.

Another colleague, Eric Brown[3], is presently writing his thesis on the same research. His thesis focus is primarily on the factors which influence productivity and their effects on scheduling. The factors will be determined based on delays which occur in highway construction operations. These factors have a direct correlation on decreasing productivity and increasing project duration.

One study based on the queuing theory was reported by Handa and Barcia[4]. The basis for their approach is the use of new dynamic optimization techniques or Optimal Control Theory. They demonstrate this technique with an earth moving operation based on solutions developed by Griffis[5]. The Optimal Control Theory uses a collection of models of a specific process and a production table calculated by Griffis in order to determine an appropriate schedule table. The scheduling table is broken down into time periods in which one period consists of 13-45 hour weeks. The schedule table suggests the optimal number of trucks that should be

present within the system, as well as the production rate and cost of the operation for a given period. The Optimal Control Theory allows the table to be applicable even if there are changes in the resources during the cyclic operation.

CYCLONE has been used in several productivity studies. Amir Tavakoli utilizes CYCLONE in two of his studies. One study's approach is to use CYCLONE to develop a set of standard models frequently encountered in road construction[6]. Another approach of Tavakoli is to accurately measure productivity for cost estimating by investigating the start-up period and steady state period of a dual cycle system, containing a processor and hauling units[7]. Travkoli uses several different simulated scenarios in order to account for varying production rates.

1.4 PROBLEM STATEMENT

This thesis concentrates on the excavation aspect of highway construction. The Tennessee Department of Transportation has two ways of categorizing soil excavation. The first process consists of moving the soil that is on the job site. The second process pertains to transporting soil to the job site. The process of moving the soil on the job site is known as road and drainage whereas the importation of the soil is known as borrow. Although these two types of

excavation are opposite in procedure, they use the same methods of excavation and transportation. Besides the origin of the soil, another difference in the methods occurs in the unloading process. Since the unloading site is on the job during borrow excavation, the soil has to be specifically placed and compacted. The placement of the soil for road and drainage may also follow the process of borrow excavation or it may be hauled off the job and spoiled.

Widening an existing road or building a new one are highway operations in which excavation accounts for a considerable amount of the project's time duration. Therefore, the duration of many projects is heavily influenced by the time associated with excavation. The analysis techniques shown throughout this thesis will determine a productivity associated with each excavation process.

The ultimate goal of this thesis is to determine a productivity and schedule time which can be associated with both borrow and road and drainage excavation. In order to complete this goal, several steps and analyses must be utilized. The first procedure is to analyze the field data and determine a probability distribution function in which the data follow. The analysis used to perform this task is the Kolmogorov-Smirnov(K-S)[8] test. The K-S test is used to

determine the type of distribution the data follow and decide if a set of data contains delays. Once the type of distribution is determined, a time associated with predicted productivity can be calculated. The time used to determine a predicted productivity is denoted as T_{95}. The next step is to divide each data set into its respective job size. The job sizes range from small, medium, and large, and are based on the total amount of soil handled throughout the duration of the project. A weighted average productivity curve for each job size is then calculated based on total production of the one day site visit. After the productivity curves are calculated, a cost estimate for each data set is determined in order to validate the productivity. Once the data is validated, the productivity curves can be used to estimate a time duration for a given job size.

Chapter 2

Data Acquisition

2.1 METHODOLOGY

Before the field data are collected, one must identify a project which includes the desired task. The site is visited after the location and date of the work is determined. At the beginning of the site visit a general information sheet is prepared to describe the project. This sheet includes the following items: prime contractor, item number, contract number, county, region, environmental conditions, construction resources, and date on which the data were collected. After this information is recorded, the data collection begins. An example of the data collected in the field is as follows:

Truck #	1	2	3
Arrival Time	0:00:00	0:00:00	0:03:12
Start Loading	0:03:16	0:07:04	0:12:55
End Loading	0:06:24	0:12:04	0:15:47

The initial step of the collection process is to determine the appropriate cycle time for the task being investigated. While construction methods vary, the basic operational cycle remains the same. In an excavation

operation, there are two specific cycle times involved in the task. One is the cycle time of the hauling unit(truck), and the other is the cycle time of the processor(excavator). The cycle time of the truck can be determined from the start reposition time of the truck to the arrival of the same truck for the next cycle. The processor cycle time is the time to process a single truckload. Once the cycles are established the field data can be reduced into cycle times and analyzed.

2.2 CONSTRUCTION METHODS

Highway construction has several different methods of operation to consider for excavation. The excavation process contains two fundamental components. The first component is the processor and the other is the hauling unit. Each resource plays a specific role in transporting the soil from the load site to the dumpsite.

The processor is the resource that extracts and places the soil into the hauling unit. Several different types of processors are available to the contractor, depending on the conditions of the job site. One type of processor is an excavator. According to observations made on this research, the excavator is utilized more often than any other processor. The reason for the frequent use of the excavator is its versatility versus a front-end loader. The front-end

loader is another processor used in excavation; however, it is limited to only certain types of excavation. The front-end loader usually requires a particular amount of margin to operate and the assistance of another resource to stockpile material. Therefore, the use of the front-end loader is not as frequent as the excavator.

The resource that actually transports the soil is the hauling unit. Hauling units are divided into two basic types. The first type is denoted as a road truck. Road trucks are tri-axle dump trucks that travel mainly on paved surfaces. The other type of hauling unit is the off-road truck. The off-road truck is categorized into two types. The two types are articulated and off-highway trucks. The off-road truck is used when the haul road does not include paved surfaces. The contractor will most likely have a higher productivity if he is able to utilize the off-road truck due to its larger hauling capacity. However, the contractor may not be able to utilize the off-road truck if the haul road is on an asphalt surface due to a limit on allowable axle loads.

Another method of excavation is the use of scrapers. Scrapers are unique in that they are both the processor and the hauling unit. However, they do require the assistance

of a pushing resource, such as a bulldozer. Also, scrapers are confined to unpaved hauling roads.

Scrapers tend to have the higher productivity of the three methods due to their maneuver time, quick load times, and quick dump times. These three items make up what is called the fixed time within a cycle. The other components are travel time and return time. A debate exists whether scrapers should be used as hauling units versus the off-road trucks. A scraper's fixed time is generally less than an off-road truck, and the fixed time has more effect on the overall cycle time of short hauling distances. Therefore, "Scrapers compete with trucks on a cost-per-year basis on hauls up to 5,000 ft"[9]. Once the hauling distance becomes relatively large, then the fixed time has less impact and the off-road truck is clearly a better hauling unit.

Another method the contractor may use is the tractor-pan. The tractor-pan method is the combination of a tractor pulling a dirt pan. A dirt pan is the containment part of a scraper. The tractor-pan method is similar to the scrapers except they usually do not require any assistance in loading. The tractor-pan method tends to have less productivity than scrapers because a tractor can not produce speeds as fast as the scraper.

A relatively new resource for pulling a dirt pan is the Challenger. The Challenger has features similar to both a tractor and a bulldozer. One positive note about the Challenger is that it has speed comparable to that of the scraper. However, the Challenger is still not in wide use but it is another method available to the contractor. Although some methods are better than others, the ultimate decision is based on the available resources to the contractor, the condition of the job site, and constraints on where the soil is located.

Chapter 3

Data Analysis

3.1 STATISTICAL MODELING

In order to determine the productivity of a construction process, the appropriate method of analysis must be decided. Excavators and front end loaders were analyzed differently from the scrapers and tractor-pans. The differences occur when determining the maximum and predicted productivity. The differences in productivity are discussed later.

The first step in analyzing the data was to determine the appropriate statistical distribution. Previous research has shown that most construction operations can be considered to be either normal or lognormal distribution[1]. The Kolmogorov-Smirnov (K-S) (Table 1)test was performed on each set of data obtained in this research. In order to perform the "K-S" test, the data must first be arranged in ascending order and the count, mean, and standard deviation must be computed.

The K-S test is a statistical analysis tool to determine if a data set conforms to a particular statistical distribution. For this research project, the data were

Table 1. K-S test on contract 4849-1, End to Arrival.

County	Claiborne		TRAVEL		Road & Drainage			
mean = (min.)	8.60		stand. dev: 1.49 (min.)		# samples= 48		zeta= 0.17197	lambda= 2.13685
		nondelay	lognormal		Normal			
order	Time(min.)	cum. freq.	cum. prob.	deviation	cum. prob.	deviation		
1	6.68	0.02083	0.08387	0.06304	0.09925	0.07842		
2	7.00	0.04167	0.13344	0.09177	0.14158	0.09991		
3	7.10	0.06250	0.15202	0.08952	0.15717	0.09467		
4	7.13	0.08333	0.15851	0.07518	0.16261	0.07928		
5	7.30	0.10417	0.19317	0.08900	0.19163	0.08747		
6	7.32	0.12500	0.19682	0.07182	0.19470	0.06970		
7	7.47	0.14583	0.23116	0.08533	0.22362	0.07779		
8	7.50	0.16667	0.23913	0.07246	0.23036	0.06370		
9	7.50	0.18750	0.23913	0.05163	0.23036	0.04286		
10	7.58	0.20833	0.25951	0.05117	0.24771	0.03938		
11	7.62	0.22917	0.26784	0.03867	0.25484	0.02567		
12	7.72	0.25000	0.29339	0.04339	0.27685	0.02685		
13	7.72	0.27083	0.29339	0.02255	0.27685	0.00602		
14	7.73	0.29167	0.29772	0.00605	0.28061	0.01106		
15	7.73	0.31250	0.29772	0.01478	0.28061	0.03189		
16	7.77	0.33333	0.30644	0.02689	0.28820	0.04514		
17	7.82	0.35417	0.31966	0.03451	0.29976	0.05441		
18	7.85	0.37500	0.32856	0.04644	0.30758	0.06742		
19	7.90	0.39583	0.34201	0.05382	0.31948	0.07636		
20	7.97	0.41667	0.36013	0.05654	0.33563	0.08103		
21	7.98	0.43750	0.36468	0.07282	0.33972	0.09778		
22	8.03	0.45833	0.37841	0.07992	0.35210	0.10624		
23	8.07	0.47917	0.38760	0.09157	0.36044	0.11873		
24	8.18	0.50000	0.41992	0.08008	0.39013	0.10987		
25	8.18	0.52083	0.41992	0.10091	0.39013	0.13070		
26	8.25	0.54167	0.43845	0.10322	0.40740	0.13426		
27	8.32	0.56250	0.45695	0.10555	0.42486	0.13764		
28	8.47	0.58333	0.49834	0.08500	0.46462	0.11871		
29	8.50	0.60417	0.50745	0.09671	0.47352	0.13065		
30	8.58	0.62500	0.53006	0.09494	0.49582	0.12918		
31	8.65	0.64583	0.54792	0.09792	0.51367	0.13217		
32	8.70	0.66667	0.56116	0.10550	0.52704	0.13963		
33	8.83	0.68750	0.59575	0.09175	0.56250	0.12500		
34	8.97	0.70833	0.62910	0.07923	0.59747	0.11086		
35	9.03	0.72917	0.64526	0.08391	0.61469	0.11448		
36	9.05	0.75000	0.64924	0.10076	0.61896	0.13104		
37	9.07	0.77083	0.65319	0.11764	0.62322	0.14762		
38	9.12	0.79167	0.66492	0.12674	0.63589	0.15577		
39	9.18	0.81250	0.68022	0.13228	0.65256	0.15994		
40	9.32	0.83333	0.70957	0.12376	0.68501	0.14833		
41	9.50	0.85417	0.74711	0.10705	0.72735	0.12682		
42	9.55	0.87500	0.75677	0.11823	0.73838	0.13662		
43	10.32	0.89583	0.87389	0.02194	0.87554	0.02029		
44	10.33	0.91667	0.87582	0.04084	0.87782	0.03885		
45	11.12	0.93750	0.94286	0.00536	0.95448	0.01698		
46	11.73	0.95833	0.97083	0.01250	0.98231	0.02397		
47	13.25	0.97917	0.99534	0.01617	0.99910	0.01993		
48	14.07	1.00000	0.99840	0.00160	0.99988	0.00012		
		maximum deviation		0.13228		0.15994		
	allowable	D(95%) for	N =48	0.19400				

compared to the normal and lognormal distributions. The deviation was determined by the absolute value of the difference between the cumulative frequency and the cumulative probabilities. After the deviations were calculated for all the data, a maximum deviation was found for both the normal and lognormal distributions. For example in contract 4849-1, the maximum deviation is 0.13228 for lognormal and 0.15994 for normal. This maximum deviation was then compared to the allowable deviation which is based on a 95% confidence level(Table 2). The values for allowable deviation with a 95% confidence is located in the column of α equals to 0.05. In order to pass the K-S test, the maximum deviation must be lower than the allowable deviation.

Table 2. Critical values for Kolmogorov-Smirnov tests.[8]

n\ α	0.20	0.10	0.05	0.01
5	0.45	0.51	**0.56**	0.67
10	0.32	0.37	**0.41**	0.49
15	0.27	0.30	**0.34**	0.40
20	0.23	0.26	**0.29**	0.36
25	0.21	0.24	**0.27**	0.32
30	0.19	0.22	**0.24**	0.29
35	0.18	0.20	**0.23**	0.27
40	0.17	0.19	**0.21**	0.25
45	0.16	0.18	**0.20**	0.24
50	0.15	0.17	**0.19**	0.23
> 50	$1.07 / \sqrt{n}$	$1.22 / \sqrt{n}$	**$1.36 / \sqrt{n}$**	$1.63 / \sqrt{n}$

where, n = number of data points

If the data fail the test, then the mean plus one standard deviation was used as a cut off point in order to separate the delay cycles from non-delay cycles. The data which were above the cut off point were considered the delay cycles. However, if the K-S test passes, the data were concluded to have no significant delays.

The K-S test was performed for road & drainage and borrow, and the results are in Tables 3 and 4. In these tables, plus 1σ denotes that the data contained significant delays and failed the K-S test and, plus 2σ means the data failed the K-S test using the mean plus one standard deviation. The mean and standard deviation of the second failed test are then used to determine a new cut off point for delays. A few selected K-S tests are presented in Appendices C and D. Although some of the data conformed to a normal distribution better than a longnormal distribution, not all data passed the K-S test for normal distribution. Since all the data passed the K-S test for the lognormal distribution, the data were analyzed using the lognormal distribution. The lognormal distribution is as follows:

Lognormal Probability Density Function:

$$f_x(x) = \frac{1}{\sqrt{2\pi}\,\zeta x} e^{\left[-\frac{1}{2}\left(\frac{\ln x - \lambda}{\zeta}\right)^2\right]} \qquad (3.1)$$

where: λ and ζ are the statistical parameters.

The parameter equations are as follows:

$$\zeta = \sqrt{\ln\left(\frac{\bar{X}^2 + \sigma^2}{\bar{X}^2}\right)} \qquad (3.2)$$

$$\lambda = \ln \bar{X} - (0.5 * \zeta^2) \qquad (3.3)$$

where, $\bar{X}$ = mean
σ = standard deviation

The headings of Tables 3 and 4, End to Arrival, simply denote that the times were the cycle times of the hauling unit. The K-S test was performed on two other times. These two times are the loading time of the processor and the reposition time of the hauling unit. The results for reposition and load times are presented as Tables B1-B4. The loading time and reposition time were only applicable for operations pertaining to excavators and front end loaders.

Table 3. K-S Test for Road and Drainage(End to Arrival).

End to Arrival(Road and Drainage)

#	Region	Contract #	County	# of Cycles	Ave. Time	Std.Dev.	D (95%)	Normal	Lognormal	Best Fit	
1	1	3564-1	Grainger	40	15.98	2.13	0.2100	0.8947	0.9073	Normal	
2	1	3564-2	Grainger	72	8.78	1.53	0.1603	0.1656	0.1325	Lognormal	
3	1	4117	Hancock	86	13.10	2.10	0.1467	0.1344	0.1427	Normal	
4	1	4123	Knox	100	43.31	5.14	0.1403	0.1299	0.1063	Lognormal	Plus 2σ
5	1	4615-1	Claiborne	82	0.64	0.08	0.1649	0.1127	0.1171	Normal	Plus 1σ
6	1	4615-2	Claiborne	87	7.37	1.02	0.1502	0.1101	0.0897	Lognormal	Plus 1σ
7	1	4835	Hamblen	78	8.32	2.04	0.1540	0.0825	0.0580	Lognormal	
8	1	4948-1	Claiborne	48	8.60	1.49	0.1940	0.1599	0.1323	Lognormal	
9	1	4948-2	Claiborne	39	12.09	2.47	0.2140	0.1678	0.1380	Lognormal	
10	1	4948-3	Claiborne	39	8.38	1.66	0.2180	0.1571	0.1357	Lognormal	Plus 1σ
11	1	5131	Knox	87	16.58	4.46	0.1458	0.1611	0.1240	Lognormal	
12	1	5214-1	Anderson morn.	100	3.54	0.31	0.1426	0.0822	0.0724	Lognormal	Plus 2σ
13	1	5214-1	Anderson after.	94	3.91	0.75	0.1475	0.1685	0.1306	Lognormal	Plus 1σ
14	1	5214-2	Anderson	94	9.42	2.63	0.1403	0.1366	0.0985	Lognormal	
15	2	3926	Rhea	92	10.46	2.17	0.1511	0.1201	0.1422	Normal	Plus 1σ
16	2	4384	McMinn	98	3.30	0.99	0.1374	0.1450	0.1086	Lognormal	
17	2	4410	White	73	11.02	1.91	0.1662	0.1323	0.1083	Lognormal	Plus 1σ
18	2	5040	Clay morn.	100	6.76	0.81	0.1741	0.1340	0.1104	Lognormal	Plus 2σ
19	2	5040	Clay after.	62	7.41	1.60	0.2150	0.2241	0.1835	Lognormal	Plus 2σ
20	3	4867	Montgomery	48	3.31	0.58	0.1963	0.0796	0.0505	Lognormal	
21	3	4952	Davidson	82	21.46	9.48	0.1502	0.1920	0.1241	Lognormal	
22	4	3915	Henderson	91	8.19	1.33	0.1458	0.0646	0.0837	Normal	Plus 1σ
23	4	4572	Weakley	76	13.99	1.14	0.1674	0.0563	0.0460	Lognormal	Plus 1σ
24	4	4696	Fayette	73	4.87	2.97	0.1592	0.2307	0.1542	Lognormal	
25	4	4737	Weakley	80	11.95	2.60	0.1521	0.1070	0.0685	Lognormal	

Table 4. K-S test for Borrow(End to Arrival).

End to Arrival(Borrow)

#	Region #	Contract #	County	# of Cycles	Ave. Time	Std. Dev.	D (95%)	Normal	Lognormal	Best Fit	
1	2	3866	Marion	37	26.33	3.24	0.2300	0.1114	0.0920	Lognormal	Plus 1σ
2	3	4017	Davidson	48	40.15	13.48	0.1940	0.0955	0.1171	Normal	
3	3	4723	Robertson	133	9.98	1.03	0.1226	0.1072	0.1035	Lognormal	Plus 1σ
4	4	3502	Carroll	59	21.53	9.30	0.1771	0.2269	0.1757	Lognormal	
5	4	3863-1	McNairy	55	15.64	2.75	0.1834	0.0755	0.1052	Normal	
6	4	3863-2	McNairy	81	5.18	0.48	0.1511	0.1079	0.1157	Lognormal	
7	4	4224	Fayette	50	14.00	3.15	0.1900	0.1291	0.0910	Lognormal	
8	4	4667-1	Shelby	95	8.27	0.85	0.1450	0.1353	0.1169	Lognormal	Plus 1σ
9	4	4667-2	Shelby	41	18.02	2.75	0.2080	0.1381	0.1142	Lognormal	
10	4	4667-3	Shelby	53	8.65	1.44	0.1868	0.1765	0.1455	Lognormal	
11	4	4678-1	Oboin	69	14.33	1.99	0.1637	0.1237	0.1105	Lognormal	
12	4	4678-2	Oboin	64	5.00	1.68	0.1700	0.1715	0.1227	Lognormal	
13	4	4696	Hardeman	60	15.58	2.97	0.1756	0.1246	0.1145	Lognormal	
14	4	4737	Weakley	91	12.69	2.78	0.1426	0.1614	0.1197	Lognormal	
15	4	4779	Oboin	83	7.83	0.86	0.1550	0.1043	0.1230	Normal	

As mentioned before, the productivity calculation differs for excavators and front end loaders. The reason for the difference is that the maximum and minimum productivity is based on the processor. Therefore, when calculating the appropriate cycle time, the processor is of primary concern. The cycle time for excavators and front end loaders was determined to be the load time plus the reposition time. The reason for including the reposition time in the cycle time is that the loader is unable to perform during the reposition. This allows for a more realistic value for the processor cycle time. However, the scrapers and tractor-pans are the processors and the end to arrival time will be utilized in determining productivity.

3.2 PREDICTED PRODUCTIVITY(T_{95})

In order to determine a predicted productivity, an appropriate cycle time must be calculated. The cycle time associated with the predicted productivity is noted as T_{95}. T_{95} is the weighted summation of the lognormal delay and lognormal non-delay cycle times for a set of data. Both the delay and non-delay cycle times have their own unique lognormal distributions. The formula and figure 1 illustrate this procedure.

$$T_{95(min.)} = \frac{\%nd^{*}(T)_{nd}}{100} + \frac{\%d^{*}(T)_{d}}{100} \quad (3.4)$$

nd = non-delay
d = delay

where T is cycle time that represents 95% of the lognormal distribution.

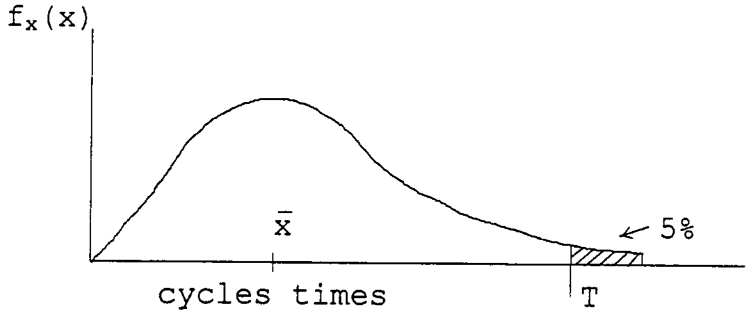

Figure 1. Lognormal Distribution Graph.

Once T_{95} is calculated, the respective productivity can be determined. Since an α of 0.05 is used in calculating the T_{95} productivity, there is a 95% confidence that at any given time the productivity of an operation is equal to or above the predicted(T_{95}) productivity.

3.3 PRODUCTIVITY CALCULATIONS

Three production rates considered in the productivity analysis are the theoretical maximum, predicted, and observed. The observed productivity was determined by the amount of material moved during the site visit divided by the total observed time. The total observed time was the actual time that the equipment worked. The following formulas were used to calculate theoretical maximum and T_{95} production rates.

Excavators and Front End Loaders

$$\text{Production rate} = \frac{60\text{min/hr} * C}{t} \quad (\text{cy/hr}) \qquad (3.5)$$

where; C = capacity of hauling unit (cy)

t = mean load + mean reposition time (Theoretical max.) (min.)

or

t = T_{95} load + reposition (T_{95} production) (min.)

Scrapers and Tractor-Pans

$$\text{Production rate} = \frac{60\text{min/hr} * C * N}{t} \ (\text{cy/hr}) \qquad (3.6)$$

where; C = capacity of hauling unit (cy)

N = equivalent number of units(N_E) (T_{95} production)
or
N = optimal number of units(N_O) (Theoretical max.)

t = T_{95} mean overall cycle time(T_{95} production)(min.)
or
t = mean overall cycle time(Theoretical max.) (min.)

The capacities for processors and hauling units were based on struck capacities of resources located in the Caterpillar Performance Handbook[10]. A summary of all the productivity calculations are presented in Tables 5 and 6.

3.4 DATA SUMMARY

In order to illustrate graphically the production rates, productivity curves were calculated. An example of the observed, theoretical maximum, and T_{95} productivity curves are illustrated in Figure 2. The theoretical maximum curve provides an upper bound and the T_{95} curve provides a lower bound for the observed production curve. Once the productivity curves were calculated for a task, all the data were assembled in their respective size groups(Table 7) based on the total quantity of the job(Figure B5-B6).

Table 5. Productivity Summary Table for Road and Drainage Excavation.

#	Region #	Contract #	County	Number of Cycles	Capacity of Unit (cy)	Mean Overall Cycle Time (minutes)	Mean Cycle Time for Processor + Repositon (minutes)	Equivalent # of Units NE	T95 - Mean Overal Cycle Time (minutes)	T95 - Load + Reposition (minutes)	Maximum Productivity (cy/hr)	Predicted Productivity (cy/hr)	Productivity Measured 1 Day Site Visit (cy/hr)	Method of Construction
1	1	3564-1	Grainger	40	48	15.98	5.60	4	19.69	9.14	515	315	482	Excavator
2	1	3564-2	Grainger	72	48	8.78	1.90	4	11.49	2.92	1518	988	1206	Front End Loader
3	1	4117	Hancock	86	34	13.10	*	3.6	16.82	*	1178	437	531	Scrapers
4	1	4123	Knox	100	12	43.31	3.73	11.11	52.25	7.65	193	94	152	Excavator
5	1	4615-1	Claiborne	82	23	6.86	2.76	2.93	7.92	3.72	499	371	449	Excavator
6	1	4615-2	Claiborne	87	23	8.00	3.36	2.84	10.58	5.28	411	262	399	Excavator
7	1	4835	Hamblen	78	25	8.32	4.34	2.55	12.01	7.00	345	214	313	Excavator
8	1	4948-1	Claiborne	48	21	8.60	4.11	3	11.24	7.21	307	175	284	Excavator
9	1	4948-2	Claiborne	39	48	12.09	6.18	3	16.52	11.82	466	244	453	Excavator
10	1	4948-3	Claiborne	39	15,30(23.46)	9.66	4.12	1.77	11.01	6.27	341	224	269	Excavator
11	1	5131	Knox	87	12	16.58	4.45	5	24.72	6.80	323	106	182	2-Excavators
12	1	5214-1	Anderson morn.	100	18	4.56	*	2.5	7.78	*	926	347	755	Scrapers
13	1	5214-1	Anderson after.	94	18	4.50	*	2.97	6.23	*	887	515	722	Scrapers
14	1	5214-2	Anderson	94	25	9.42	3.60	2.85	14.25	5.74	834	261	373	Front End Loader
15	2	3926	Rhea	92	34,40(35.31)	11.49	*	3.69	15.64	*	841	500	681	Scrapers
16	2	4384	McMinn	98	18	3.30	*	1.92	5.13	*	958	405	608	Scrapers
17	2	4410	White	73	18,28(21.68)	12.34	*	2.64	16.92	*	474	203	321	Scrapers
18	2	5040	Clay morn.	100	23	9.36	2.34	3.7	11.49	3.63	1179	380	714	2-Excavators
19	2	5040	Clay after.	62	23	10.50	2.42	3.44	14.67	3.86	1138	357	634	2-Excavators
20	3	4867	Montgomery	48	18	3.31	*	2	4.35	*	762	497	630	Scrapers
21	3	4952	Davidson	82	12,21,27(17.59)	21.46	3.26	4.63	39.31	5.08	647	208	311	2-Excavators
22	4	3915	Henderson	91	12	8.66	1.95	4.6	11.53	3.38	370	213	313	Excavator
23	4	4572	Weakley	76	12	14.69	1.51	5.85	16.99	2.03	476	355	269	Excavator
24	4	4696	Fayette	73	18	4.87	*	1.97	10.49	*	652	203	402	Scrapers
25	4	4737	Weakley	80	12	11.95	2.14	2.96	16.64	3.49	337	206	172	Excavator
26	4	4886	Weakley	61	28	8.14	*	1.91	9.70	*	571	331	403	Challengers

* Note: Contracts which contained Scrapers or Dirt Pans

Table 6. Productivity Summary Table for Borrow Excavation.

#	Region #	Contract #	County	Number of Cycles	Capacity of Unit (cy)	Mean Overall Cycle Time (minutes)	Mean Cycle Load + Reposition Time (minutes)	Equivalent # of Units NE	Optimal # of Units N_0	T95 Based on Load & Reposition (minutes)	T95 Based on Mean Cycle Time (minutes)	Maximum Productivity (cy/hr)	Predicted Productivity (cy/hr)	Productivity Measured 1-Day Site Visit (cy/hr)	Method of Construction
1	2	3866	Marion	37	12	28.6	2.76	3.8		5.32	34.89	261	135	107	Track Loader
2	3	4017	Davidson	48	12	40.1	3.06	3.3		4.14	65.14	236	174	77	Excavator
3	3	4723	Robertson	133	12	10.4	3.73	3		5.45	12.63	193	132	170	Excavator
4	4	3502	Carroll	59	12	21.5	2.83	4.3		4.53	39.02	254	159	178	Excavator
5	4	3863-1	McNairy	55	12	15.6	2.00	5		3.11	20.53	359	231	233	Excavator
6	4	3863-2	McNairy	81	23	5.2	2.24	2		2.77	6.01	615	497	488	Excavator
7	4	4224	Fayette	50	12	14.0	1.77	5.5		3.47	19.68	406	207	317	Excavator
8	4	4667-1	Shelby	95	15	8.8	1.94	4.6		2.97	10.68	463	303	433	Excavator
9	4	4667-2	Shelby	41	20	18.0	3.26	1.8	5.53	*	22.87	368	95	144	Tractor & Pans
10	4	4667-3	Shelby	53	20	8.6	1.86	2.8	4.65	*	11.20	645	301	366	Tractor & Pans
11	4	4678-1	Obion	83	12	14.3	2.11	5.4		3.18	17.82	512	340	270	Excavator
12	4	4678-2	Obion	70	18	5.0	1.73	2	2.89		8.11	624	178	385	Scrapers
13	4	4696	Hardeman	60	12	15.6	3.81	3.8		7.73	20.89	189	93	163	Excavator
14	4	4737	Weakley	91	12	12.7	2.49	3.6		3.66	17.69	289	197	200	Excavator
15	4	4779	Obion	83	17	8.2	1.98	2.5		3.35	9.98	514	305	260	Excavator

*Note Contracts which contained Scrapers or Dirt Pans

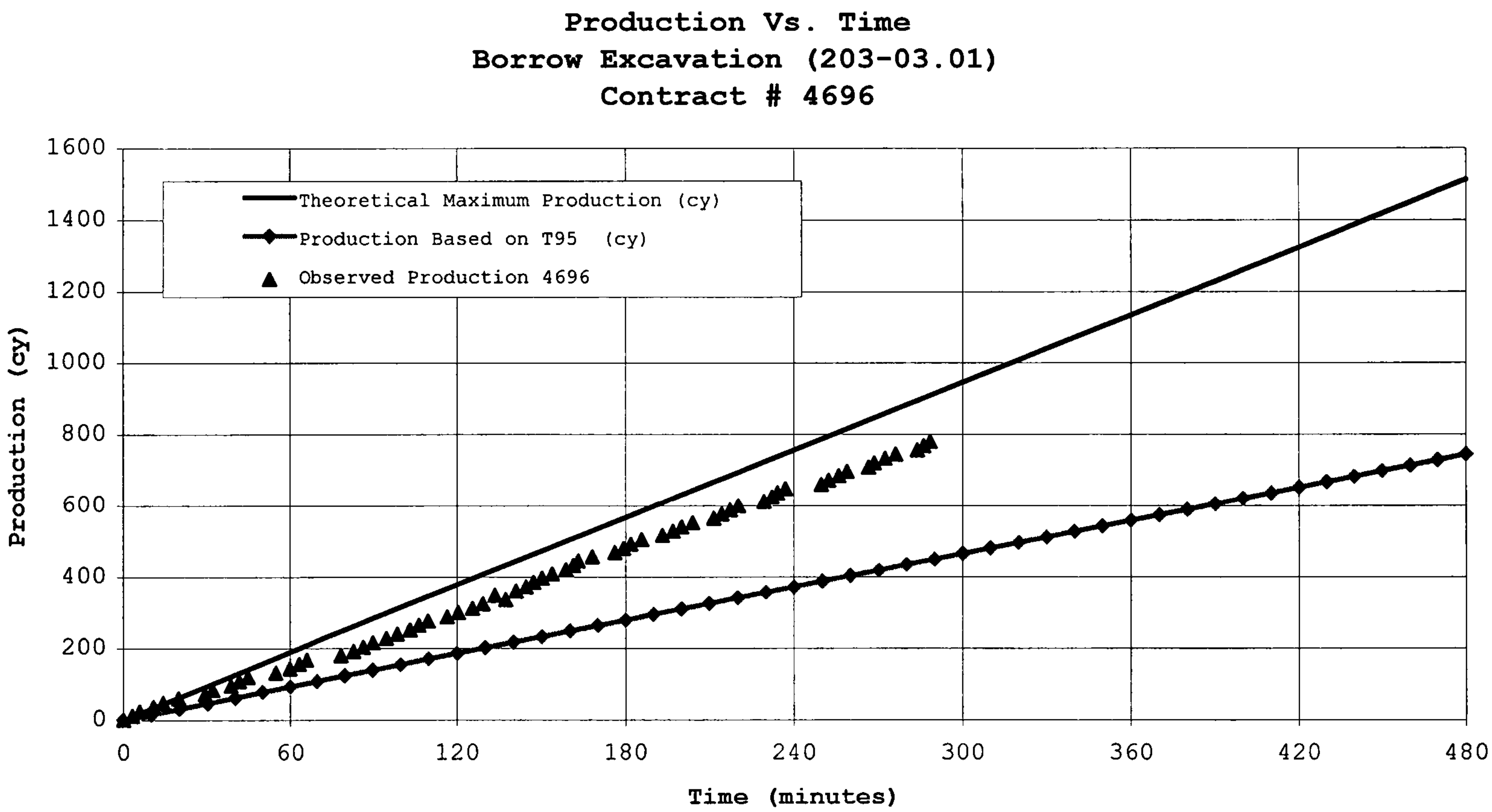

Figure 2. Production Curves for Contract 4696(Borrow).

Table 7. Job Size Breakdown for Road & Drainage and Borrow Excavation.

Road & Drainage

Size	**Range (cy)**		
Small	0	-	500,000
Medium	500,000	-	1,000,000
Large	1,000,000	-	up

Borrow

Size	**Range (cy)**		
Small	0	-	100,000
Large	100,000	-	up

After each set of data were inserted into its respective job size, a weighted average productivity curve was calculated(Figure A1-A5). The weighted average productivity curves represent excavators, front end loaders, scrapers, and tractor-pans. The weighted averages were based on the total observed production during the one-day site visit and represents an eight hour working day. The curves also portray a single operation for a single site for an eight hour day.

Chapter 4

Data Comparison

4.1 COST ESTIMATES

In order to demonstrate the reliability of the data, a productivity cost estimate[11] was calculated for each measured task and an average for each region was calculated. The cost estimates are based on the resources and labor force present during the data collection. An example of an individual contract cost estimate is in Table 8.

Table 8. Cost Estimate for Contract 4948-1.

Item # 203-01
Road&Drainage Excavation
Contract # 4948-1
County: Claiborne
Region: I

Equipment:					
Model	Quantity	Rate/Month ($)	Rate/Hour ($)	Operation Cost/Hour ($)	Total Cost/Hour ($)
Komatsu PC400LC Excavator	1	11,500	65.34	16.25	81.59
Volvo A35 Haul Trucks	3	12,000	68.18	21.64	269.45
Cat D6E Dozer	1	6,800	38.64	8.21	46.85
Grizzly Shaker Roller	1	6,900	39.20	10.43	49.63
					447.53

Labor:					
Classification	Quantity	Rate/Hour ($/hr)	Crew Hour Worked/Hour	Total Cost ($/hr)	Crew Rate ($/hr)
Foreman	1	12.80	0.25	3.20	
Class A Operator	1	11.80	1.0	11.80	
Class B Operator	2	10.04	2.0	20.08	
Truck Driver	3	8.89	3.0	26.67	
			6.25	61.75	9.88

Total Cost/Hour ($)	Observed Production Rate (cy/hr)	Unit Cost ($/cy)
533.98	284	1.88

The equipment costs were based on manufacturers' suggested rental rates, and the labor costs were determined using the appropriate state wage rates. A 40% burden was added to the labor cost to account for FICA, Workmen's Compensation, unemployment insurance, and other non-direct costs. Once a total cost per hour was determined, a unit cost was calculated by dividing the total cost per hour by the observed production rate. The following equation illustrates this procedure.

$$\text{Unit Cost}(\$/cy) = \frac{\text{Total Cost} \quad (\$/hr)}{\text{Production Rate} \quad (cy/hr)} \qquad (4.1)$$

After a cost estimate was calculated for each contract, a weighted average unit cost based on production was calculated for each region. The summary of cost estimates are located in Tables 9 and 10.

The calculated weighted average for road and drainage is \$1.81/cy compared to the TDOT average of \$2.31/cy. The likely difference is that profit was not included in the calculation of the observed unit cost. Profit was also excluded in the calculation of a unit cost for borrow excavation. The unit costs for borrow excavation are \$1.97/cy for observed and \$3.16/cy for TDOT. The larger margin between observed and TDOT unit costs for borrow

Table 9. Summary of Cost Estimates for Road & Drainage Excavation.

No.	Contract #	Region	County	Method	Production Rate (cy/hr)	Total Time of Operation (HR)	Production (cy)	Material Cost ($/hr)	Equipment Cost ($/hr)	Labor Cost ($/hr)	* Total Cost ($/hr)	Unit Cost ($/cy)	Actual Unit Bid Price ($/cy)
1	3564	I	Grainger	Excavator	482	3.98	1920	-	1228.06	60.60	1312.90	2.72	3.53
2	3564-2	I	Grainger	ront End Loade	1206	2.87	3457	-	1,525.11	82.44	1640.52	1.36	3.53
3	4117	I	Hancock	Scrapers	531	5.76	3059	-	1,033.91	83.08	1150.22	2.17	
4	4123	I	Knox	Excavator	152	7.92	1203	-	563.43	15.00	584.43	3.84	5.25
5	4615-1	I	Claiborne	Excavator	449	4.35	1954	-	868.31	75.24	973.65	2.17	
6	4615-2	I	Claiborne	Excavator	399	5.24	2091	-	824.28	103.67	969.42	2.43	
7	4835	I	Hamblen	Excavator	313	6.31	1976	**	364.52	52.86	438.53	1.40	
8	4948-1	I	Claiborne	Excavator	284	3.55	1009	**	447.53	61.75	533.98	1.88	
9	4948-2	I	Claiborne	Excavator	453	4.13	1872	**	1014.01	71.79	1114.52	2.46	
10	4948-3	I	Claiborne	Excavator	269	3.40	913	-	514.20	62.90	602.26	2.24	
11	5131	I	Knox	2-Excavators	182	6.28	1143	-	604.79	66.96	698.54	3.84	
12	5214-1	I	Anderson morn.	Scrapers	755	2.38	1800	-	520.94	63.44	609.76	0.81	
13	5214-1	I	nderson after	Scrapers	722	2.37	1711	-	520.94	63.44	609.76	0.84	
14	5214-2	I	nderson after	ront End Loade	373	6.51	2427	-	688.08	80.07	800.18	2.15	
15	3926	II	Rhea	Scrapers	681	4.98	3391	-	802.74	52.96	876.89	1.29	1.58
16	4384	II	McMinn	Scrapers	608	2.96	1801	-	279.54	36.52	330.66	0.54	1.64
17	4410	II	White	Scrapers	321	5.13	1648	-	442.89	53.40	517.65	1.61	2.50
18	5040	II	Clay morn.	2-Excavators	714	3.22	2300	**	692.56	137.15	884.57	1.24	
19	5040	II	Clay after.	2-Excavators	634	2.25	1425	**	692.56	137.15	884.57	1.40	
20	4867	III	Montgomery	Scrapers	630	1.37	864	-	486.75	43.36	547.45	0.87	
21	4952	III	Davidson	2-Excavators	311	4.98	1548	**	972.26	91.33	1100.12	3.54	
22	3915	IV	Henderson	Excavator	313	3.68	1150	-	425.38	74.30	529.40	1.69	2.00
23	4572	IV	Weakley	Excavator	269	3.39	911	-	430.83	31.88	475.46	1.77	2.24
24	4696	IV	Fayette	Scrapers	402	3.27	1315	-	282.38	30.12	324.55	0.81	2.45
25	4737	IV	Weakley	Excavator	172	5.79	997	-	250.25	25.04	285.30	1.66	3.55
26	4886	IV	Weakley	Challengers	403	5.04	2033	-	201.91	23.28	234.50	0.58	

BASED ON 1-DAY SITE VISIT

		Production
Region I Weighted Average Unit Cost =	**2.05**	26534.80
Region II Weighted Average Unit Cost =	**1.22**	10564.38
Region III Weighted Average Unit Cost =	**2.58**	2411.90
Region IV Weighted Average Unit Cost =	**1.42**	5254.70
		44765.77

Weighted Average Unit Cost = **1.81**

1996 TDOT AVG. UNIT PRICE

Region I = **2.98**
Region II = **2.77**
Region III = **2.20**
Region IV = **1.94**

Average Unit Price = **2.31**

* **NOTE:** 40% Labor Burden has been added to the Labor Cost to arrive at Total Cost. Unit Cost do not contain Mark-Up and Overhead.

Average based on total production in each region.

** **NOTE:** This Data was taken on Rock Excavation.

Table 10. Summary of Cost Estimates for Borrow Excavation.

No.	Contract #	Region	County	Method of Construction	Production Rate (cy/hr)	Total Time of Operation (HR)	Production (cy)	Material Cost ($/hr)	Equipment Cost ($/hr)	Labor Cost ($/hr)	* Total Cost ($/hr)	Unit Cost ($/cy)	Actual Unit Bid Price ($/cy)
1	3866	II	Marion	Track Loader	107	5.14	550	-	222.37	15.00	243.37	2.27	4.40
2	4017	III	Davidson	Excavator	77	7.64	589	**	311.66	44.68	374.21	4.86	6.50
3	4723	III	Robertson	Excavator	170	10.18	1730	-	330.91	45.13	394.09	2.32	8.45
4	3502	IV	Carroll	Excavator	178	4.39	782	-	406.20	35.08	455.32	2.56	3.00
5	3863-1	IV	McNairy	Excavator	233	3.35	781	-	328.19	35.08	377.30	1.62	5.00
6	3863-2	IV	McNairy	Excavator	488	4.01	1956	-	462.07	52.86	536.07	1.10	5.00
7	4224	IV	Fayette	Excavator	317	2.58	817	-	402.09	44.68	464.64	1.47	2.80
8	4667-1	IV	Shelby	Excavator	433	3.50	1516	-	576.46	79.53	687.80	1.59	
9	4667-2	IV	Shelby	Tractor & Pans	144	6.53	940	-	304.12	65.20	395.40	2.75	
10	4667-3	IV	Shelby	Tractor & Pans	366	3.22	1180	-	416.44	83.52	533.37	1.46	
11	4678-1	IV	Obion	Excavator	270	3.55	959	-	279.54	33.32	326.18	1.21	2.40
12	4678-2	IV	Obion	Scrapers	385	2.84	1094	-	426.61	35.08	475.72	1.24	2.40
13	4696	IV	Hardeman	Excavator	114	4.78	545	-	273.69	35.08	322.80	2.83	
14	4737	IV	Weakley	Excavator	200	6.00	1200	-	340.22	45.12	403.39	2.02	5.00
15	4779	IV	Obion	Excavator	260	5.75	1495	-	581.48	91.87	710.09	2.73	3.80

BASED ON 1-DAY SITE VISIT		Production
Region I Weighted Average Unit Cost =	0.00	0.00
Region II Weighted Average Unit Cost =	2.27	550.46
Region III Weighted Average Unit Cost =	2.96	2318.77
Region IV Weighted Average Unit Cost =	1.80	13263.75
		16132.98
Weighted Average Unit Cost =	**1.98**	

1996 TDOT AVG. UNIT PRICE

Region I = **4.47**
Region II = **4.28**
RegionIII = **2.54**
Region IV = **3.4**

Average Unit Price = **3.16**

Average based on total production in each region.

* **NOTE:** 40% Labor Burden has been added to the Labor Cost to arrive at Total Cost. Unit Cost do not contain Mark-Up and Overhead.

** **NOTE:** This Data was taken on Rock Excavation.

excavation is that cost of material is not included in the calculation of the observed unit cost. Although profit and material costs are absent in the calculation of unit cost, it is apparent that the observed unit cost adequately correlates with TDOT's average unit cost.

4.2 PRODUCTIVITY

The Tennessee Department of Transportation has published productivity rates[12] which have been used to schedule project durations. TDOT's rates are shown in Table 12 along with productivity rates developed within this research. TDOT determines job size based on the cost of the total contract. TDOT's job size breakdown is located in Table 11.

Table 11. Job Size Breakdown for TDOT.

Road & Drainage and Borrow excavation

Size	Range ($)		
Small	0	-	500,000
Medium	500,000	-	2,500,000
Large	2,500,000	-	up

Table 12. Production Rates for Research Data and TDOT.

Road & Drainage Excavation

	Research Data				TDOT
	Single Operation				Single Operation
Size	Theoretical Max. (cy/day)	Observed (cy/day)	T_{95} (cy/day)		TDOT Production (cy/day)
Large	6360	4639	3461		8000
Medium	6336	4403	2812		5000
Small	4112	2614	2338		2500

Borrow Excavation

	Research Data				TDOT
	Single Operation				Single Operation
Size	Theoretical Max. (cy/day)	Observed (cy/day)	T_{95} (cy/day)		TDOT Production (cy/day)
Large	3840	2645	2324		5000
Medium	-	-	-		2000
Small	2372	1527	1458		1000

TDOT estimated their productivity rates by consulting general contractors and TDOT personnel. TDOT's productivity rates represent a single operation for an eight hour day.

After the productivity rates were calculated, they were compared to productivity rates presently employed by TDOT and TDOT field book data. When the field book data were analyzed, the allocation of working days was found to be inconsistent. A historical examination of contract 3564 proved that not all working days were recorded. For example, one working day was charged in the month of January and 87,000 cubic yards of material ware processed. Therefore, the inconsistent allocation of working days prevented a comparison of this thesis's scheduling technique to historical data.

Many contracts containing excavation operations have been extended either by not allocating working days or by extending calendar day deadlines. TDOT extends these contracts in order to avoid claims which in most cases cost the state not only time extension but addition financial compensation. The allocated time for many contracts is too short because the productivity rates used for scheduling are too high. Since the state's productivity rates are not calculated from any specific method, TDOT does not have a means for defending claims for time extension.

The productivity rates developed in this research are calculated from field data collection and statistical analysis techniques. The T_{95} productivity rates reflect productivities with a 95% confidence level. The research productivity rates provide a means for predicting a schedule that will permit the Department of Transportation a method of scheduling task duration with a high degree of confidence and at the same time provide reasonable time objectives for highway contractors.

Chapter 5

Conclusions

The inconsistent scheduling of highway construction operations has concerned contractors and TDOT personnel for many years. In order to alleviate scheduling dilemmas, this research has developed a methodology for calculating a predicted productivity for highway construction operations. This thesis analyzed borrow and road and drainage excavation operations and developed productivity rates for various job sizes which are used for determining task durations.

In order to decrease schedule duration conflicts for highway excavation operations, a statistical technique for determining predicted productivity rates has been developed in this thesis. The calculated productivity rates provide for scheduling task times with a high degree of confidence. This thesis not only supplies TDOT with a better scheduling technique but also provides a means of defending the productivity rates used for scheduling.

Through the course of this research, one recommendation for future excavation studies was developed. Highway construction operations containing large amounts of excavation tend to have concurrent earthmoving processes.

The recommendation for future studies is to analyze these concurrent processes and determine their effect on productivity and scheduling.

List of References

LIST OF REFERENCES

1. Halpin, D.W., Riggs, L.S. Planning and Analysis of Construction Operations. John Wiley & Sons, INC. New York, 41-96.1992

2. Abdulghafour, A.B. "Modeling Highway Construction Tasks to Determine Project Duration." Ph.D. dissertation. University of Tennessee, Knoxville.1998

3. Brown, Eric R. "Factors Affecting Productivity of Highway Construction Operations." University of Tennessee, Knoxville. In process of completing thesis for submittal in May of 1999.

4. Handa, V.K. and Barcia, R.M. "Construction Production Planning," *J. Construction Engineering and Management* (ASCE), **112**(2), 163-177. 1986

5. Griffis, Jr., F.H., "Optimizing Haul Fleet Size Using Queuing Theroy," in *Reading Costs in Engineering*, Vol. 1, ASCE, pp. 531-544. 1979

6. Tavakoli, A. ,"Productivity Analysis of Construction Operations," *J. Construction Engineering and Management* (ASCE), **111**(1), 31-39. 1985

7. Tavakoli, A.,"Transient Response Analysis of a Dual Cycle System," *J. Construction Engineering and Management* (ASCE), **112**(3), pp. 403-410. 1986

8. Ang, A. and Tang, W. Probability Concepts in Engineering Planning and Design: Volume I-Basic Principles. New York: John Wiley & Sons. 1975

9. *Better Roads* , "Should you haul with a truck or a scraper," October 1993,pp. 35-36.

10. *Caterpillar Performance Handbook* . Peoria, Illinois. 1994

11. Deatherage, H. Construction Estimating Course Notes(Spring). University of Tennessee, Knoxville, Civil Engineering Department. 1997

12. Tennessee Department of Transportation (TDOT), Letter from Carl M. Wood, Jr. to Dennis C. Cook, subject "Determination of Contract Time". date: October 5, 1993.

Appendices

Appendix A

Summary Figures

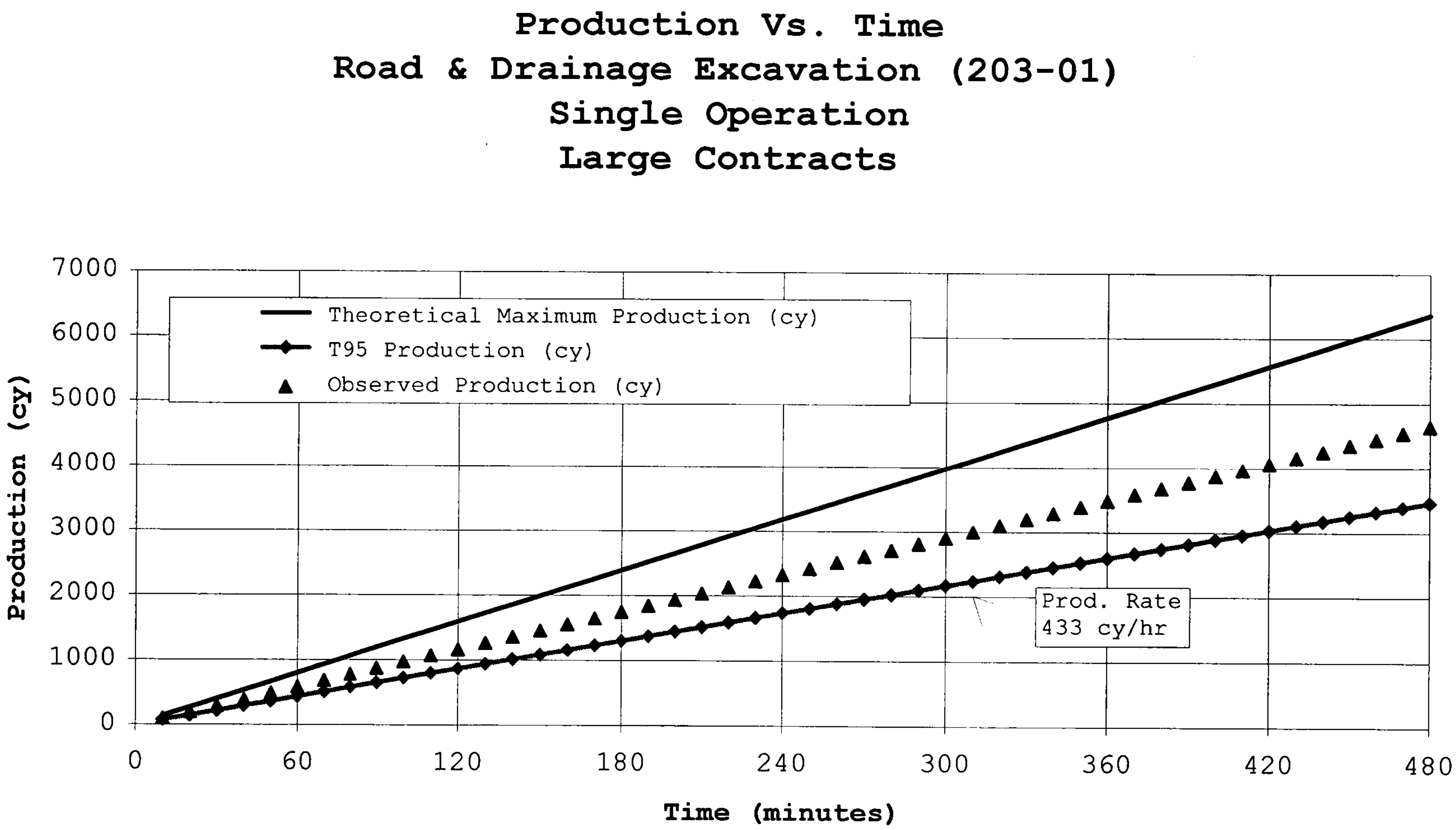

Figure A1: **Productivity Curves for Large Operations(Road Drainage).**

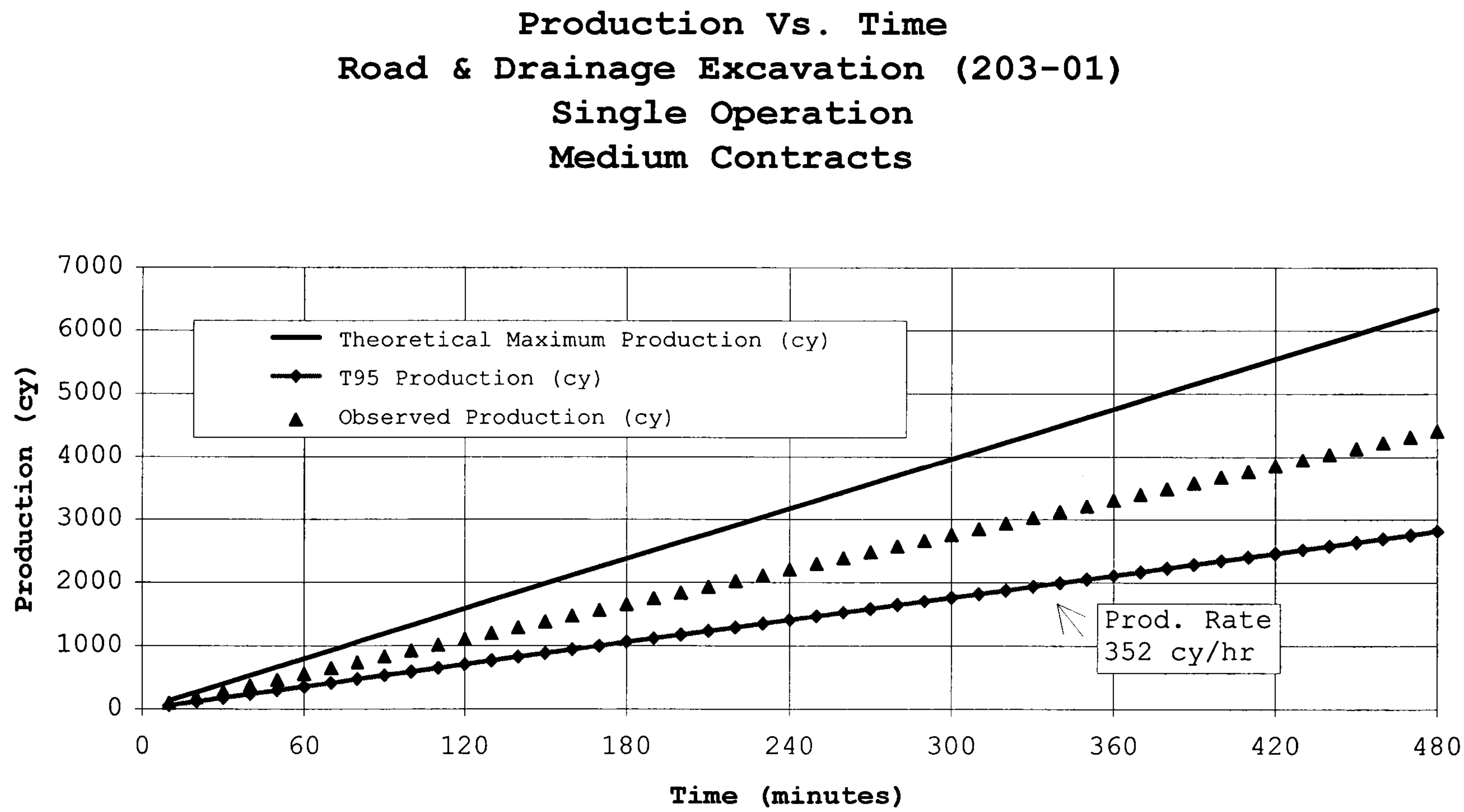

Figure A2: Productivity Curves for Medium Operations(Road Drainage).

Production Vs. Time
Road & Drainage Excavation (203-01)
Single Operation
Small Contracts

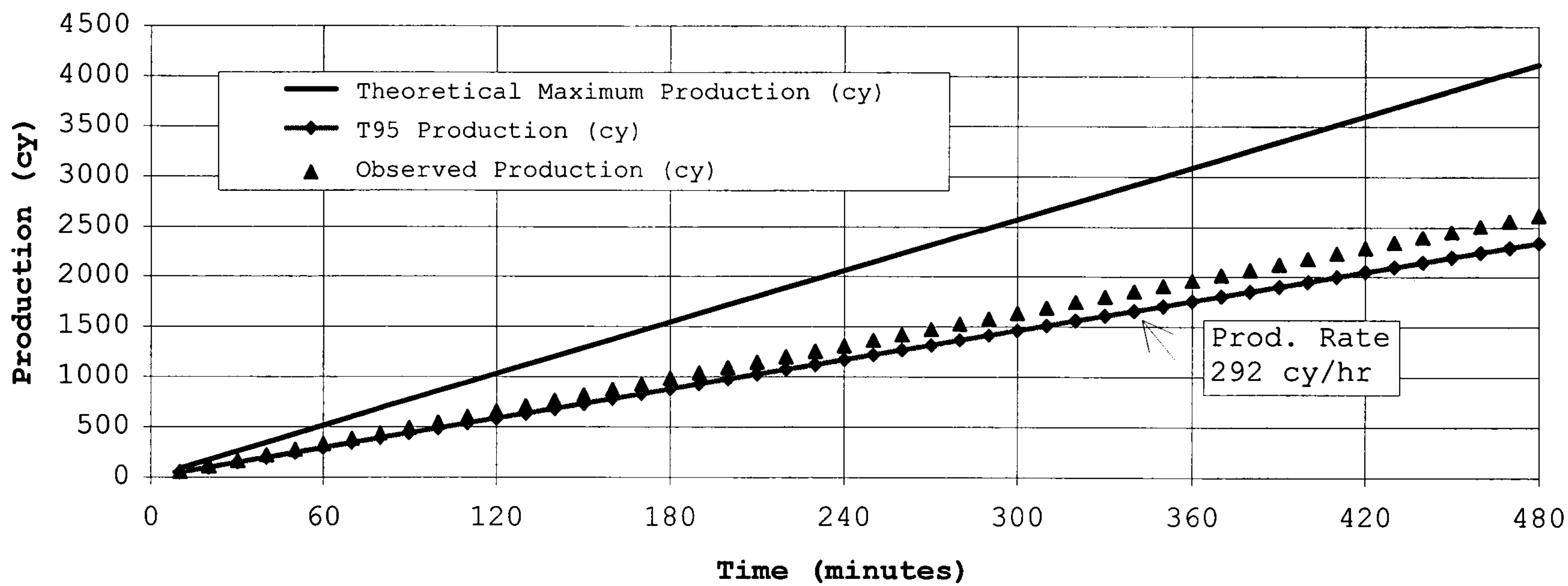

Figure A3: Productivity Curves for Small Operations(Road Drainage).

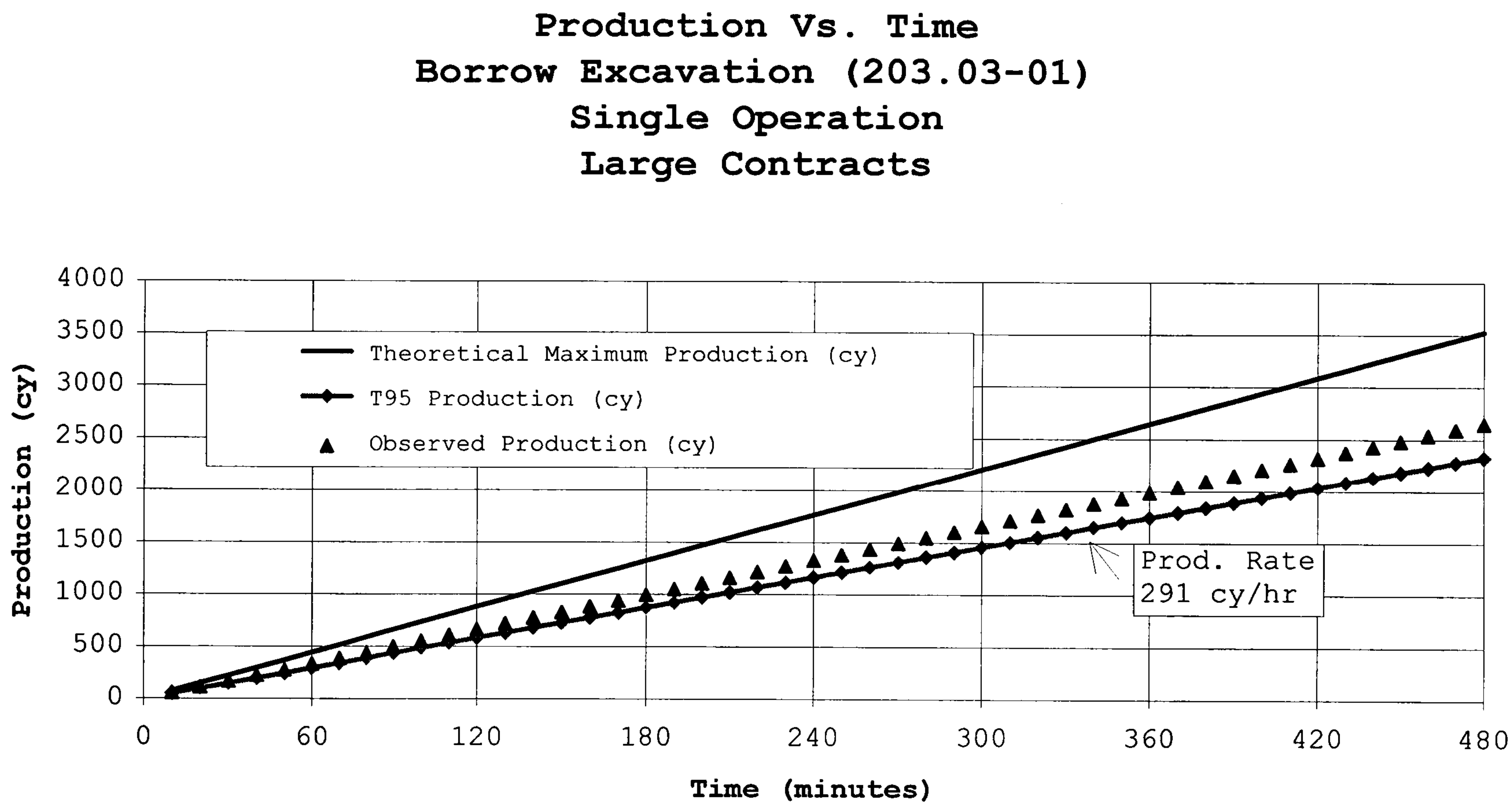

Figure A4: Productivity Curves for Large Operations(Borrow).

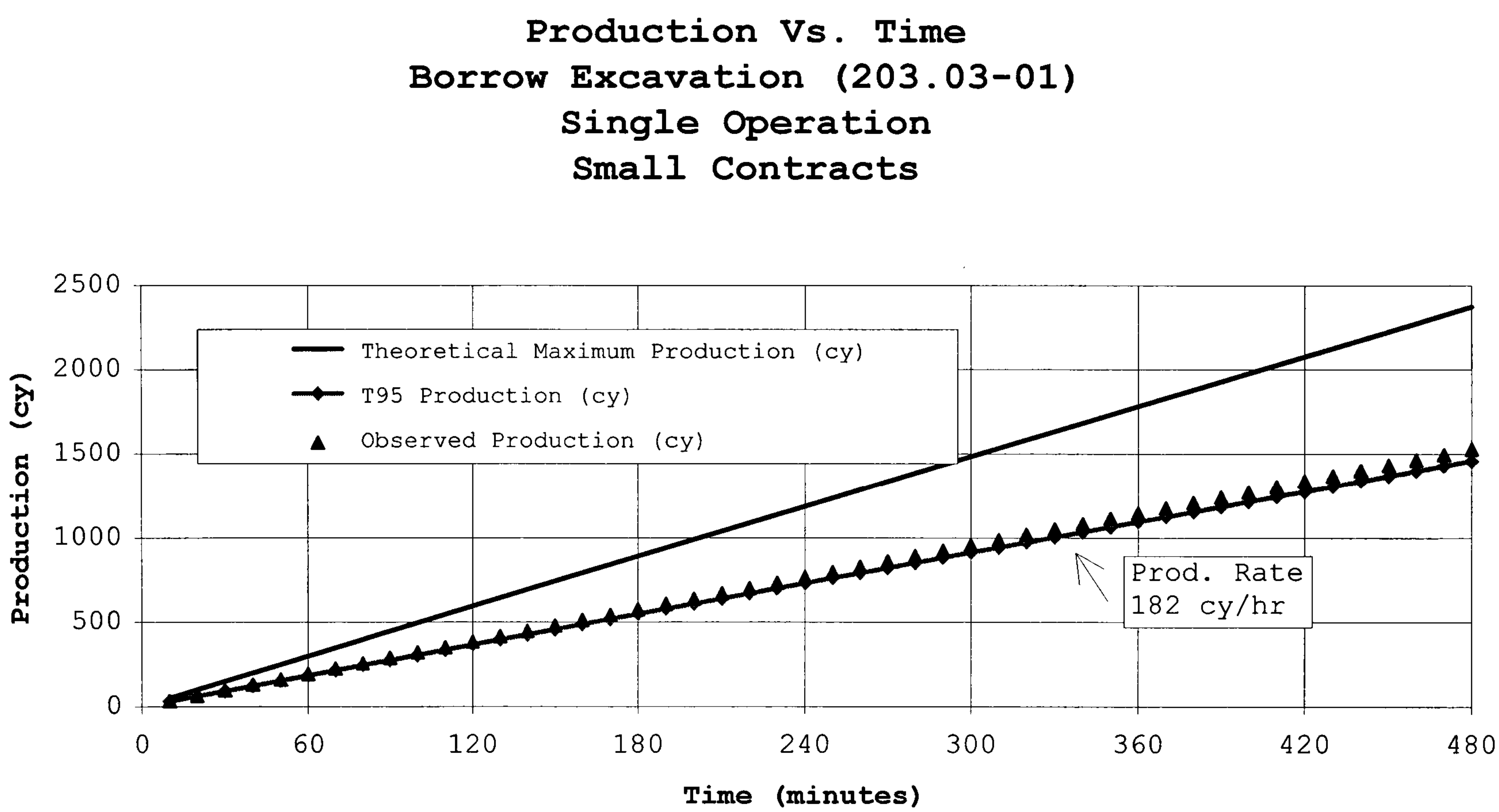

Figure A5: Productivity Curves for Small Operations(Borrow).

Appendix B

Summary Tables

Table B1. K-S Results for Reposition(Road and Drainage).

#	Region	Contract #	County	# of Cycles	Ave. Time	Std.Dev.	D (95%)	Normal	Lognormal	Best Fit	
1	1	3564-1	Grainger	40	1.27	0.81	0.2100	0.2176	0.1024	**Lognormal**	
2	1	3564-2	Grainger	72	0.62	0.31	0.1603	0.2004	0.1081	**Lognormal**	
3	1	4117	Hancock	86	0.99	0.46	0.1467	0.1598	0.0902	**Lognormal**	
4	1	4123	Knox	100	1.40	0.93	0.1388	0.2178	0.0987	**Lognormal**	Plus 1σ
5	1	4615-1	Claiborne	82	0.64	0.08	0.1649	0.1127	0.1171	**Normal**	Plus 2σ
6	1	4615-2	Claiborne	87	0.88	0.32	0.1434	0.1784	0.1085	**Lognormal**	
7	1	4835	Hamblen	78	0.99	0.56	0.1530	0.1321	0.0882	**Lognormal**	
8	1	4948-1	Claiborne	48	1.33	0.99	0.1940	0.2134	0.0933	**Lognormal**	
9	1	4948-2	Claiborne	39	1.44	1.61	0.2140	0.2950	0.1523	**Lognormal**	
10	1	4948-3	Claiborne	39	0.99	0.55	0.2180	0.1374	0.1705	**Normal**	
11	1	5131	Knox	87	0.77	0.56	0.1403	0.1161	0.1079	**Lognormal**	
12	1	5214-1	Anderson morn.	100	0.54	0.28	0.1374	0.1833	0.1289	**Lognormal**	
13	1	5214-1	Anderson after.	94	0.63	0.32	0.1426	0.1842	0.1339	**Lognormal**	
14	1	5214-2	Anderson	94	0.91	0.50	0.1381	0.1969	0.1235	**Lognormal**	
15	2	3926	Rhea	92	0.42	0.46	0.1442	0.2883	0.1167	**Lognormal**	
16	2	4384	McMinn	98	0.60	0.36	0.1374	0.1780	0.0739	**Lognormal**	
17	2	4410	White	73	1.51	1.55	0.1592	0.2079	0.0956	**Lognormal**	
18	2	5040	Clay morn.	100	0.70	0.35	0.1360	0.2041	0.1271	**Lognormal**	
19	2	5040	Clay after.	62	0.65	0.29	0.1727	0.0992	0.1370	**Normal**	
20	3	4867	Montgomery	48	0.57	0.33	0.1963	0.1430	0.0587	**Lognormal**	
21	3	4952	Davidson	82	0.99	0.47	0.1450	0.1292	0.1168	**Lognormal**	
22	4	3915	Henderson	91	0.90	0.46	0.1388	0.1226	0.0443	**Lognormal**	
23	4	4572	Weakley	76	0.34	0.12	0.1923	0.2309	0.1692	**Lognormal**	Plus 2σ
24	4	4696	Fayette	73	0.46	0.29	0.1592	0.1878	0.0757	**Lognormal**	
25	4	4737	Weakley	80	0.65	0.28	0.1550	0.1290	0.0933	**Lognormal**	
26	4	4886	Weakley	61	0.98	0.47	0.1741	0.1095	0.1513	**Normal**	

Table B2. K-S Results for Loading(Road and Drainage).

#	Region	Contract #	County	# of Cycles	Ave. Time	Std.Dev.	D (95%)	Normal	Lognormal	Best Fit	
1	1	3564-1	Grainger	40	10.37	1.99	0.2100	0.1230	0.0861	**Lognormal**	
2	1	3564-2	Grainger	72	1.28	0.24	0.1603	0.0805	0.0796	**Lognormal**	
3	1	4117	Hancock	86	0.74	0.20	0.1403	0.1461	0.0944	**Lognormal**	
4	1	4123	Knox	100	2.35	0.40	0.1360	0.0587	0.0556	**Lognormal**	
5	1	4615-1	Claiborne	82	2.10	0.22	0.1475	0.0984	0.0817	**Lognormal**	
6	1	4615-2	Claiborne	87	2.48	0.72	0.1434	0.1508	0.1331	**Lognormal**	
7	1	4835	Hamblen	78	3.35	0.87	0.1530	0.1166	0.0699	**Lognormal**	
8	1	4948-1	Claiborne	48	2.96	0.40	0.1940	0.0839	0.0718	**Lognormal**	Plus 1σ
9	1	4948-2	Claiborne	39	4.74	1.54	0.2140	0.1481	0.0993	**Lognormal**	
10	1	4948-3	Claiborne	39	3.13	0.62	0.2180	0.1230	0.1312	**Normal**	
11	1	5131	Knox	87	3.65	1.29	0.2004	0.1403	0.1373	**Lognormal**	
12	1	5214-1	Anderson morn.	100	0.61	0.14	0.1360	0.0811	0.0666	**Lognormal**	
13	1	5214-1	Anderson after.	94	0.59	0.12	0.1418	0.0868	0.0722	**Lognormal**	
14	1	5214-2	Anderson	94	2.69	0.66	0.1381	0.1301	0.0882	**Lognormal**	
15	2	3926	Rhea	92	2.10	1.12	0.1388	0.1605	0.0636	**Lognormal**	
16	2	4384	McMinn	98	0.59	0.12	0.1434	0.0971	0.0670	**Lognormal**	
17	2	4410	White	73	1.24	0.59	0.1592	0.1831	0.1055	**Lognormal**	
18	2	5040	Clay morn.	100	1.65	0.34	0.1360	0.1403	0.1227	**Lognormal**	
19	2	5040	Clay after.	62	1.77	0.49	0.1727	0.2100	0.1675	**Lognormal**	
20	3	4867	Montgomery	48	0.85	0.36	0.1963	0.2627	0.1858	**Lognormal**	
21	3	4952	Davidson	82	2.08	0.54	0.1450	0.0984	0.0472	**Lognormal**	
22	4	3915	Henderson	91	1.05	0.31	0.1388	0.1606	0.1043	**Lognormal**	
23	4	4572	Weakley	76	1.07	0.10	0.1560	0.1291	0.1110	**Lognormal**	
24	4	4696	Fayette	73	1.20	0.37	0.1592	0.1177	0.0960	**Lognormal**	
25	4	4737	Weakley	80	1.47	0.21	0.1493	0.1041	0.0829	**Lognormal**	
26	4	4886	Weakley	61	1.96	0.56	0.1741	0.1334	0.1029	**Lognormal**	

Table B3. K-S Results for Reposition(Borrow).

#	Region #	Contract #	County	# of Cycles	Ave. Time	Std. Dev.	D (95%)	Normal	Lognormal	Best Fit	
1	2	3866	Marion	37	0.91	0.96	0.2140	0.2173	0.1273	Lognormal	
2	3	4017	Davidson	48	0.99	0.35	0.1980	0.1255	0.0953	Lognormal	
3	3	4723	Robertson	133	0.66	0.27	0.1202	0.0999	0.0784	Lognormal	
4	4	3502	Carroll	59	0.98	0.63	0.1713	0.2234	0.1289	Lognormal	
5	4	3863-1	McNairy	55	0.71	0.47	0.1713	0.1588	0.1471	Lognormal	
6	4	3863-2	McNairy	81	0.58	0.14	0.1467	0.1091	0.0649	Lognormal	
7	4	4224	Fayette	50	0.71	0.73	0.1674	0.1718	0.0880	Lognormal	
8	4	4667-1	Shelby	95	0.36	0.09	0.1581	0.0819	0.0799	Lognormal	Plus 1σ
9	4	4667-2	Shelby	41	2.56	1.11	0.1920	0.0858	0.0801	Lognormal	
10	4	4667-3	Shelby	53	0.57	0.06	0.1801	0.7310	0.0900	Lognormal	Plus 1σ
11	4	4678-1	Oboin	83	0.70	0.50	0.1493	0.2245	0.1509	Lognormal	
12	4	4678-2	Oboin	70	0.48	0.48	0.1687	0.2296	0.1540	Lognormal	Plus 1σ
13	4	4696	Hardeman	60	1.32	1.52	0.1700	0.2981	0.1236	Lognormal	
14	4	4737	Weakley	91	0.67	0.23	0.1450	0.0935	0.0858	Lognormal	Plus 1σ
15	4	4779	Oboin	83	0.45	0.10	0.1687	0.1322	0.1635	Normal	Plus 1σ

Table B4. K-S Results for Loading(Borrow).

#	Region #	Contract #	County	# of Cycles	Ave. Time	Std. Dev.	D (95%)	Normal	Lognormal	Best Fit	
1	2	3866	Marion	37	1.85	0.47	0.1980	0.1173	0.0672	**Lognormal**	
2	3	4017	Davidson	48	2.07	0.25	0.1920	0.0752	0.0511	**Lognormal**	
3	3	4723	Robertson	133	2.93	0.57	0.1145	0.1252	0.0950	**Lognormal**	
4	4	3502	Carroll	59	1.85	0.29	0.1687	0.0755	0.0619	**Lognormal**	
5	4	3863-1	McNairy	55	1.22	0.11	0.1771	0.1568	0.1392	**Lognormal**	Plus 1σ
6	4	3863-2	McNairy	81	1.66	0.16	0.1467	0.0974	0.0827	**Lognormal**	
7	4	4224	Fayette	50	0.99	0.17	0.1713	0.1118	0.0923	**Lognormal**	Plus 1σ
8	4	4667-1	Shelby	95	1.40	0.18	0.1360	0.0544	0.0474	**Lognormal**	
9	4	4667-2	Shelby	41	0.70	0.25	0.1920	0.1612	0.1385	**Lognormal**	
10	4	4667-3	Shelby	53	1.26	0.23	0.1727	0.0896	0.0694	**Lognormal**	
11	4	4678-1	Oboin	83	1.40	0.30	0.1493	0.1143	0.0891	**Lognormal**	
12	4	4678-2	Oboin	70	1.03	0.22	0.1700	0.1318	0.0916	**Lognormal**	
13	4	4696	Hardeman	60	2.49	0.71	0.1687	0.1215	0.0908	**Lognormal**	
14	4	4737	Weakley	91	1.56	0.30	0.1403	0.0601	0.0368	**Lognormal**	Plus 1σ
15	4	4779	Oboin	83	1.65	0.34	0.1450	0.1002	0.0668	**Lognormal**	

Table B5. Job Size Breakdown for Road and Drainage Excavation.

ROAD & DRAINAGE EXCAVATION

Contract	Region	County	TDOT Engineer	Quantity (cy)
			SMALL	
4123	I	Knox	Harry Carr	370,417.00
5131	I	Knox	Harry Carr	183,634.00
5214	I	Anderson	Bobby Parks	308,340.73
4867	III	Montgomery	Patrick Murry	441,381.00
4952	III	Davidson	Jerry Hatcher	238,210.00
4572	IV	Weakley	Richard Adkisson	294,801.00
4737	IV	Weakley	James Moore	111,494.00
4886	IV	Weakley	Richard Adkisson	248,325.00
			MEDIUM	
4835	I	Hamblem	Lawrence Dodson	978,026.25
3926	II	Rhea	Melvin Webb	861,855.00
5040	II	Clay	Frank Campbell	720,555.00
3915	IV	Henderson	Chuck Rychen	528,457.00
4696	IV	Fayette	Scott Taylor	577,615.00
			LARGE	
3564	I	Grainger	Lawrence Dodson	1,867,469.00
4117	I	Hancock	Chad McCurray	1,691,312.00
4615	I	Claiborne	Bobby Parks	1,398,406.00
4948	I	Claiborne	Bobby Parks	3,240,756.00
4384	II	McMinn	Bill Webb Jr.	1,104,507.00
4410	II	White	J. C. Weaver	1,242,040.00

Table B6. Job Size Breakdown for Borrow Excavation

BORROW EXCAVATION

Contract	Region	County	TDOT Engineer	Quantity (cy)
			SMALL	
3866	II	Marion	Russell Layne	24,500.00
4723	III	Robertson	Ronnie Wooten	4,381.00
4696	IV	Fayette	Scott Taylor	80,000.00
4737	IV	Weakley	Jim Moore	11,822.00
4779	IV	Obion	John Steele	88,805.00
			LARGE	
4017	III	Davidson	Ken Colbert	130,986.00
3502	IV	Carroll	Chuck Rychen	366,014.00
3863	IV	McNairy	Mark Harwell	260,000.00
4224	IV	Fayette	Scott Taylor	308,882.00
4667	IV	Shelby	Les Hayes	117,938.00
4678	IV	Obion	John Steele	341,399.00

Appendix C

Sample K-S Tests for Road & Drainage Excavation

County	Rhea		End To Arrival		Road & Drainage		11/24/98	
Contract	3926							
mean =	10.46		stand. dev=	2.17	# samples 81		zi=	lambda=
							0.20487	2.32692

order	Time	**nondelay** cum. freq.	**lognormal** cum. prob.	deviation	**Normal** cum. prob.	deviation
1	4.13	0.01235	0.00000	0.01234	0.00174	0.01061
2	4.42	0.02469	0.00002	0.02467	0.00262	0.02207
3	4.62	0.03704	0.00005	0.03699	0.00348	0.03356
4	4.93	0.04938	0.00018	0.04920	0.00534	0.04404
5	6.50	0.06173	0.01316	0.04857	0.03365	0.02808
6	6.67	0.07407	0.01796	0.05612	0.03983	0.03425
7	7.13	0.08642	0.03856	0.04786	0.06211	0.02431
8	7.82	0.09877	0.09323	0.00554	0.11088	0.01212
9	7.97	0.11111	0.10966	0.00146	0.12454	0.01342
10	8.87	0.12346	0.24012	0.11666	0.23051	0.10706
11	8.92	0.13580	0.24874	0.11294	0.23759	0.10179
12	9.02	0.14815	0.26631	0.11816	0.25209	0.10395
13	9.15	0.16049	0.29035	0.12985	0.27214	0.11164
14	9.28	0.17284	0.31499	0.14215	0.29294	0.12010
15	9.33	0.18519	0.32436	0.13918	0.30093	0.11574
16	9.35	0.19753	0.32750	0.12997	0.30361	0.10608
17	9.45	0.20988	0.34646	0.13658	0.31993	0.11006
18	9.48	0.22222	0.35282	0.13060	0.32546	0.10323
19	9.57	0.23457	0.36881	0.13424	0.33943	0.10486
20	9.62	0.24691	0.37845	0.13153	0.34792	0.10100
21	9.65	0.25926	0.38489	0.12563	0.35362	0.09436
22	9.68	0.27160	0.39134	0.11973	0.35936	0.08775
23	9.75	0.28395	0.40426	0.12031	0.37093	0.08698
24	9.75	0.29630	0.40426	0.10796	0.37093	0.07463
25	9.78	0.30864	0.41072	0.10208	0.37676	0.06811
26	9.82	0.32099	0.41719	0.09620	0.38261	0.06163
27	9.87	0.33333	0.42689	0.09356	0.39145	0.05812
28	9.98	0.34568	0.44951	0.10383	0.41228	0.06660
29	10.00	0.35802	0.45273	0.09471	0.41528	0.05725
30	10.02	0.37037	0.45595	0.08558	0.41828	0.04791
31	10.07	0.38272	0.46560	0.08289	0.42731	0.04460
32	10.15	0.39506	0.48162	0.08656	0.44245	0.04739
33	10.18	0.40741	0.48800	0.08059	0.44853	0.04113
34	10.18	0.41975	0.48800	0.06825	0.44853	0.02878
35	10.22	0.43210	0.49436	0.06226	0.45463	0.02253
36	10.23	0.44444	0.49754	0.05309	0.45768	0.01323
37	10.27	0.45679	0.50387	0.04708	0.46379	0.00700
38	10.27	0.46914	0.50387	0.03473	0.46379	0.00535
39	10.28	0.48148	0.50703	0.02555	0.46684	0.01464
40	10.33	0.49383	0.51647	0.02264	0.47603	0.01780
41	10.40	0.50617	0.52897	0.02280	0.48829	0.01788
42	10.47	0.51852	0.54136	0.02285	0.50057	0.01795
43	10.55	0.53086	0.55669	0.02583	0.51591	0.01495
44	10.65	0.54321	0.57481	0.03160	0.53429	0.00892

45	10.65	0.55556	0.57481	0.01925	0.53429	0.02127
46	10.70	0.56790	0.58375	0.01585	0.54345	0.02445
47	10.78	0.58025	0.59846	0.01821	0.55867	0.02158
48	10.80	0.59259	0.60137	0.00878	0.56171	0.03089
49	10.87	0.60494	0.61292	0.00798	0.57381	0.03113
50	10.87	0.61728	0.61292	0.00436	0.57381	0.04348
51	10.92	0.62963	0.62147	0.00816	0.58283	0.04679
52	11.05	0.64198	0.64379	0.00181	0.60669	0.03529
53	11.10	0.65432	0.65197	0.00235	0.61554	0.03878
54	11.13	0.66667	0.65736	0.00930	0.62140	0.04526
55	11.18	0.67901	0.66537	0.01365	0.63015	0.04886
56	11.20	0.69136	0.66801	0.02335	0.63305	0.05831
57	11.27	0.70370	0.67846	0.02525	0.64458	0.05913
58	11.35	0.71605	0.69124	0.02481	0.65880	0.05725
59	11.43	0.72840	0.70370	0.02470	0.67280	0.05560
60	11.48	0.74074	0.71102	0.02972	0.68108	0.05966
61	11.55	0.75309	0.72060	0.03249	0.69199	0.06109
62	11.57	0.76543	0.72296	0.04247	0.69469	0.07074
63	11.70	0.77778	0.74138	0.03640	0.71591	0.06186
64	11.77	0.79012	0.75027	0.03985	0.72625	0.06387
65	11.83	0.80247	0.75895	0.04352	0.73640	0.06607
66	11.97	0.81481	0.77566	0.03916	0.75611	0.05870
67	12.03	0.82716	0.78370	0.04347	0.76566	0.06150
68	12.32	0.83951	0.81550	0.02401	0.80384	0.03567
69	12.35	0.85185	0.81899	0.03286	0.80807	0.04378
70	12.68	0.86420	0.85118	0.01301	0.84724	0.01696
71	13.00	0.87654	0.87736	0.00082	0.87917	0.00263
72	13.32	0.88889	0.89962	0.01073	0.90608	0.01720
73	13.40	0.90123	0.90487	0.00364	0.91237	0.01113
74	13.68	0.91358	0.92102	0.00744	0.93140	0.01782
75	13.80	0.92593	0.92694	0.00102	0.93824	0.01231
76	13.88	0.93827	0.93094	0.00734	0.94279	0.00451
77	13.90	0.95062	0.93171	0.01891	0.94366	0.00695
78	14.10	0.96296	0.94043	0.02253	0.95339	0.00958
79	14.13	0.97531	0.94178	0.03353	0.95487	0.02044
80	14.15	0.98765	0.94245	0.04521	0.95559	0.03206
81	14.87	1.00000	0.96538	0.03462	0.97895	0.02105
		maximum deviation		0.14215		0.12010
		D(95%) for N =81		0.15111		

County Rhea LOAD Road & Drainage 11/24/98
Contact 3926
mean = 2.10 stand. dev= 1.12 # samples 96 zi= 0.49819 lambda= 0.61949

order	Time	nondelay cum. freq.	lognormal cum. prob.	deviation	Normal cum. prob.	deviation
1	0.58	0.01042	0.01003	0.00039	0.08667	0.07625
2	0.67	0.02083	0.01983	0.00101	0.09906	0.07822
3	0.67	0.03125	0.01983	0.01142	0.09906	0.06781
4	0.68	0.04167	0.02233	0.01933	0.10168	0.06002
5	0.73	0.05208	0.03102	0.02106	0.10987	0.05779
6	0.78	0.06250	0.04149	0.02101	0.11852	0.05602
7	0.82	0.07292	0.04947	0.02344	0.12454	0.05162
8	0.90	0.08333	0.07284	0.01049	0.14053	0.05720
9	0.95	0.09375	0.08908	0.00467	0.15077	0.05702
10	0.97	0.10417	0.09484	0.00933	0.15428	0.05012
11	0.98	0.11458	0.10076	0.01382	0.15786	0.04327
12	1.00	0.12500	0.10685	0.01815	0.16148	0.03648
13	1.02	0.13542	0.11308	0.02233	0.16517	0.02975
14	1.03	0.14583	0.11947	0.02637	0.16890	0.02307
15	1.03	0.15625	0.11947	0.03678	0.16890	0.01265
16	1.05	0.16667	0.12599	0.04067	0.17269	0.00602
17	1.08	0.17708	0.13945	0.03764	0.18043	0.00335
18	1.13	0.18750	0.16054	0.02696	0.19244	0.00494
19	1.15	0.19792	0.16779	0.03013	0.19655	0.00137
20	1.17	0.20833	0.17514	0.03320	0.20071	0.00762
21	1.18	0.21875	0.18258	0.03617	0.20492	0.01383
22	1.30	0.22917	0.23674	0.00757	0.23587	0.00670
23	1.35	0.23958	0.26073	0.02115	0.24988	0.01029
24	1.37	0.25000	0.26880	0.01880	0.25464	0.00464
25	1.37	0.26042	0.26880	0.00838	0.25464	0.00577
26	1.38	0.27083	0.27688	0.00605	0.25946	0.01138
27	1.38	0.28125	0.27688	0.00437	0.25946	0.02179
28	1.42	0.29167	0.29311	0.00144	0.26922	0.02244
29	1.43	0.30208	0.30123	0.00085	0.27417	0.02791
30	1.45	0.31250	0.30936	0.00314	0.27917	0.03333
31	1.47	0.32292	0.31750	0.00542	0.28421	0.03871
32	1.50	0.33333	0.33374	0.00041	0.29442	0.03892
33	1.50	0.34375	0.33374	0.01001	0.29442	0.04933
34	1.52	0.35417	0.34185	0.01232	0.29958	0.05458
35	1.53	0.36458	0.34994	0.01464	0.30479	0.05979
36	1.53	0.37500	0.34994	0.02506	0.30479	0.07021
37	1.55	0.38542	0.35801	0.02741	0.31004	0.07538
38	1.57	0.39583	0.36606	0.02978	0.31532	0.08051
39	1.57	0.40625	0.36606	0.04019	0.31532	0.09093
40	1.57	0.41667	0.36606	0.05061	0.31532	0.10134
41	1.60	0.42708	0.38207	0.04502	0.32601	0.10107
42	1.67	0.43750	0.41367	0.02383	0.34781	0.08969
43	1.67	0.44792	0.41367	0.03425	0.34781	0.10011
44	1.75	0.45833	0.45217	0.00616	0.37577	0.08256
45	1.77	0.46875	0.45971	0.00904	0.38145	0.08730
46	1.82	0.47917	0.48200	0.00283	0.39863	0.08053
47	1.82	0.48958	0.48200	0.00758	0.39863	0.09095

48	1.85	0.50000	0.49655	0.00345	0.41020	0.08980
49	1.85	0.51042	0.49655	0.01386	0.41020	0.10022
50	1.88	0.52083	0.51085	0.00998	0.42184	0.09899
51	1.92	0.53125	0.52489	0.00636	0.43356	0.09769
52	1.92	0.54167	0.52489	0.01678	0.43356	0.10811
53	1.93	0.55208	0.53180	0.02028	0.43944	0.11264
54	1.97	0.56250	0.54543	0.01707	0.45124	0.11126
55	1.98	0.57292	0.55213	0.02078	0.45715	0.11576
56	1.98	0.58333	0.55213	0.03120	0.45715	0.12618
57	2.02	0.59375	0.56533	0.02842	0.46901	0.12474
58	2.02	0.60417	0.56533	0.03883	0.46901	0.13515
59	2.03	0.61458	0.57183	0.04276	0.47495	0.13963
60	2.03	0.62500	0.57183	0.05317	0.47495	0.15005
61	2.03	0.63542	0.57183	0.06359	0.47495	0.16046
62	2.10	0.64583	0.59707	0.04876	0.49876	0.14707
63	2.15	0.65625	0.61524	0.04101	0.51662	0.13963
64	2.23	0.66667	0.64406	0.02260	0.54630	0.12037
65	2.23	0.67708	0.64406	0.03302	0.54630	0.13078
66	2.32	0.68750	0.67107	0.01643	0.57572	0.11178
67	2.40	0.69792	0.69631	0.00161	0.60473	0.09319
68	2.45	0.70833	0.71062	0.00229	0.62186	0.08647
69	2.50	0.71875	0.72433	0.00558	0.63877	0.07998
70	2.55	0.72917	0.73745	0.00828	0.65540	0.07376
71	2.63	0.73958	0.75805	0.01847	0.68246	0.05712
72	2.63	0.75000	0.75805	0.00805	0.68246	0.06754
73	2.68	0.76042	0.76968	0.00927	0.69825	0.06217
74	2.68	0.77083	0.76968	0.00115	0.69825	0.07258
75	2.70	0.78125	0.77344	0.00781	0.70344	0.07781
76	2.73	0.79167	0.78079	0.01088	0.71368	0.07799
77	2.92	0.80208	0.81731	0.01523	0.76681	0.03528
78	2.98	0.81250	0.82908	0.01658	0.78468	0.02782
79	3.07	0.82292	0.84275	0.01984	0.80586	0.01706
80	3.08	0.83333	0.84535	0.01202	0.80993	0.02340
81	3.28	0.84375	0.87345	0.02970	0.85470	0.01095
82	3.33	0.85417	0.87964	0.02548	0.86468	0.01051
83	3.33	0.86458	0.87964	0.01506	0.86468	0.00009
84	3.42	0.87500	0.88929	0.01429	0.88025	0.00525
85	3.48	0.88542	0.89645	0.01103	0.89176	0.00634
86	3.58	0.89583	0.90631	0.01048	0.90750	0.01166
87	3.70	0.90625	0.91662	0.01037	0.92364	0.01739
88	4.05	0.91667	0.94110	0.02444	0.95938	0.04271
89	4.07	0.92708	0.94206	0.01498	0.96066	0.03358
90	4.08	0.93750	0.94301	0.00551	0.96191	0.02441
91	4.43	0.94792	0.95956	0.01165	0.98155	0.03363
92	4.80	0.95833	0.97162	0.01329	0.99214	0.03380
93	4.88	0.96875	0.97379	0.00504	0.99361	0.02486
94	4.98	0.97917	0.97617	0.00300	0.99505	0.01589
95	5.28	0.98958	0.98203	0.00755	0.99780	0.00822
96	5.33	1.00000	0.98285	0.01715	0.99809	0.00191
		maximum deviation		0.06359		0.16046
		D(95%) for N =96		0.13880		

County	Rhea		Reposition		Road & Drainage		11/24/98	
Contract	3926							
mean =	0.42		stand. dev=	0.46	# samples 89		zi=	lambda=
							0.89986	-1.28394
		nondelay	**lognormal**		**Normal**			
order	Time	cum. freq.	cum. prob.	deviation	cum. prob	deviation		
1	0.04	0.01124	0.01577	0.00453	0.20922	0.19799		
2	0.05	0.02247	0.02857	0.00610	0.21548	0.19301		
3	0.05	0.03371	0.02857	0.00514	0.21548	0.18177		
4	0.07	0.04494	0.05676	0.01181	0.22615	0.18120		
5	0.08	0.05618	0.09100	0.03482	0.23710	0.18092		
6	0.08	0.06742	0.09100	0.02359	0.23710	0.16969		
7	0.08	0.07865	0.09100	0.01235	0.23710	0.15845		
8	0.10	0.08989	0.12882	0.03893	0.24834	0.15846		
9	0.10	0.10112	0.12882	0.02769	0.24834	0.14722		
10	0.10	0.11236	0.12882	0.01646	0.24834	0.13598		
11	0.10	0.12360	0.12882	0.00522	0.24834	0.12475		
12	0.10	0.13483	0.12882	0.00601	0.24834	0.11351		
13	0.10	0.14607	0.12882	0.01725	0.24834	0.10228		
14	0.10	0.15730	0.12882	0.02849	0.24834	0.09104		
15	0.10	0.16854	0.12882	0.03972	0.24834	0.07980		
16	0.12	0.17978	0.16835	0.01142	0.25986	0.08009		
17	0.12	0.19101	0.16835	0.02266	0.25986	0.06885		
18	0.12	0.20225	0.16835	0.03389	0.25986	0.05762		
19	0.13	0.21348	0.20831	0.00517	0.27165	0.05817		
20	0.13	0.22472	0.20831	0.01641	0.27165	0.04693		
21	0.13	0.23596	0.20831	0.02765	0.27165	0.03570		
22	0.13	0.24719	0.20831	0.03888	0.27165	0.02446		
23	0.13	0.25843	0.20831	0.05012	0.27165	0.01322		
24	0.13	0.26966	0.20831	0.06135	0.27165	0.00199		
25	0.15	0.28090	0.24781	0.03309	0.28370	0.00280		
26	0.15	0.29213	0.24781	0.04433	0.28370	0.00843		
27	0.17	0.30337	0.28627	0.01710	0.29600	0.00737		
28	0.17	0.31461	0.28627	0.02834	0.29600	0.01861		
29	0.17	0.32584	0.28627	0.03958	0.29600	0.02984		
30	0.20	0.33708	0.35878	0.02170	0.32131	0.01577		
31	0.20	0.34831	0.35878	0.01047	0.32131	0.02701		
32	0.22	0.35955	0.39252	0.03297	0.33429	0.02526		
33	0.23	0.37079	0.42449	0.05371	0.34747	0.02332		
34	0.23	0.38202	0.42449	0.04247	0.34747	0.03455		
35	0.25	0.39326	0.45472	0.06146	0.36084	0.03242		
36	0.25	0.40449	0.45472	0.05023	0.36084	0.04365		
37	0.27	0.41573	0.48324	0.06751	0.37438	0.04135		
38	0.27	0.42697	0.48324	0.05628	0.37438	0.05258		
39	0.27	0.43820	0.48324	0.04504	0.37438	0.06382		
40	0.27	0.44944	0.48324	0.03380	0.37438	0.07506		
41	0.28	0.46067	0.51011	0.04944	0.38808	0.07259		
42	0.28	0.47191	0.51011	0.03820	0.38808	0.08383		
43	0.30	0.48315	0.53541	0.05226	0.40192	0.08123		
44	0.30	0.49438	0.53541	0.04103	0.40192	0.09246		

45	0.30	0.50562	0.53541	0.02979	0.40192	0.10370
46	0.30	0.51685	0.53541	0.01855	0.40192	0.11493
47	0.30	0.52809	0.53541	0.00732	0.40192	0.12617
48	0.32	0.53933	0.55921	0.01988	0.41588	0.12344
49	0.32	0.55056	0.55921	0.00864	0.41588	0.13468
50	0.32	0.56180	0.55921	0.00259	0.41588	0.14591
51	0.32	0.57303	0.55921	0.01383	0.41588	0.15715
52	0.32	0.58427	0.55921	0.02506	0.41588	0.16839
53	0.32	0.59551	0.55921	0.03630	0.41588	0.17962
54	0.32	0.60674	0.55921	0.04754	0.41588	0.19086
55	0.35	0.61798	0.60264	0.01534	0.44411	0.17386
56	0.35	0.62921	0.60264	0.02658	0.44411	0.18510
57	0.35	0.64045	0.60264	0.03781	0.44411	0.19634
58	0.37	0.65169	0.62243	0.02925	0.45835	0.19334
59	0.37	0.66292	0.62243	0.04049	0.45835	0.20458
60	0.37	0.67416	0.62243	0.05173	0.45835	0.21581
61	0.37	0.68539	0.62243	0.06296	0.45835	0.22705
62	0.37	0.69663	0.62243	0.07420	0.45835	0.23828
63	0.37	0.70787	0.62243	0.08543	0.45835	0.24952
64	0.37	0.71910	0.62243	0.09667	0.45835	0.26076
65	0.38	0.73034	0.64105	0.08929	0.47263	0.25771
66	0.40	0.74157	0.65857	0.08300	0.48695	0.25462
67	0.40	0.75281	0.65857	0.09424	0.48695	0.26586
68	0.40	0.76404	0.65857	0.10547	0.48695	0.27709
69	0.40	0.77528	0.65857	0.11671	0.48695	0.28833
70	0.42	0.78652	0.67506	0.11146	0.50129	0.28523
71	0.43	0.79775	0.69059	0.10716	0.51562	0.28213
72	0.45	0.80899	0.70521	0.10377	0.52994	0.27905
73	0.47	0.82022	0.71900	0.10122	0.54422	0.27601
74	0.53	0.83146	0.76677	0.06469	0.60058	0.23088
75	0.63	0.84270	0.82101	0.02168	0.68100	0.16169
76	0.65	0.85393	0.82846	0.02547	0.69373	0.16020
77	0.67	0.86517	0.83553	0.02964	0.70623	0.15894
78	0.72	0.87640	0.85465	0.02175	0.74223	0.13418
79	0.98	0.88764	0.92046	0.03282	0.88978	0.00214
80	1.00	0.89888	0.92319	0.02431	0.89640	0.00248
81	1.07	0.91011	0.93300	0.02289	0.92000	0.00989
82	1.10	0.92135	0.93733	0.01598	0.93016	0.00881
83	1.10	0.93258	0.93733	0.00475	0.93016	0.00243
84	1.27	0.94382	0.95444	0.01062	0.96685	0.02303
85	1.48	0.95506	0.96891	0.01385	0.98938	0.03432
86	1.77	0.96629	0.98027	0.01397	0.99822	0.03193
87	1.92	0.97753	0.98422	0.00669	0.99940	0.02187
88	1.93	0.98876	0.98459	0.00417	0.99947	0.01071
89	2.67	1.00000	0.99408	0.00592	1.00000	0.00000
		maximum deviation		0.11671		0.28833
		D(95%) for N =89		0.14416		

County	Knox		End to Arrival		Road & Drainage		11/24/98	
Contract	4123							
mean =	43.31		stand. dev=	5.14	# samples 94		zi=	lambda=
							0.11836	3.76143

		nondelay	**lognormal**		**Normal**	
order	Time	cum. freq.	cum. prob.	deviation	cum. prob.	deviation
1	34.62	0.01064	0.03332	0.02268	0.04549	0.03485
2	35.13	0.02128	0.04373	0.02245	0.05594	0.03466
3	35.18	0.03191	0.04485	0.01294	0.05704	0.02513
4	36.15	0.04255	0.07106	0.02850	0.08193	0.03938
5	36.45	0.05319	0.08104	0.02785	0.09112	0.03793
6	36.93	0.06383	0.09908	0.03525	0.10750	0.04367
7	36.95	0.07447	0.09974	0.02527	0.10810	0.03364
8	37.63	0.08511	0.12962	0.04451	0.13483	0.04972
9	37.83	0.09574	0.13931	0.04357	0.14344	0.04770
10	38.22	0.10638	0.15908	0.05270	0.16098	0.05459
11	38.55	0.11702	0.17751	0.06049	0.17731	0.06029
12	38.68	0.12766	0.18520	0.05754	0.18413	0.05647
13	38.80	0.13830	0.19208	0.05378	0.19023	0.05193
14	38.88	0.14894	0.19707	0.04813	0.19466	0.04572
15	38.95	0.15957	0.20111	0.04153	0.19824	0.03867
16	39.07	0.17021	0.20828	0.03807	0.20462	0.03441
17	39.08	0.18085	0.20932	0.02847	0.20554	0.02469
18	39.25	0.19149	0.21981	0.02832	0.21488	0.02339
19	39.30	0.20213	0.22300	0.02088	0.21773	0.01560
20	39.42	0.21277	0.23055	0.01778	0.22447	0.01170
21	39.42	0.22340	0.23055	0.00714	0.22447	0.00106
22	39.55	0.23404	0.23931	0.00527	0.23230	0.00174
23	39.58	0.24468	0.24153	0.00315	0.23429	0.01039
24	39.92	0.25532	0.26417	0.00885	0.25462	0.00069
25	40.07	0.26596	0.27463	0.00868	0.26407	0.00189
26	40.22	0.27660	0.28526	0.00866	0.27369	0.00291
27	40.30	0.28723	0.29123	0.00399	0.27911	0.00813
28	40.45	0.29787	0.30209	0.00421	0.28899	0.00888
29	40.53	0.30851	0.30818	0.00033	0.29455	0.01396
30	40.58	0.31915	0.31185	0.00730	0.29791	0.02124
31	40.65	0.32979	0.31677	0.01301	0.30242	0.02737
32	40.70	0.34043	0.32048	0.01994	0.30582	0.03461
33	40.78	0.35106	0.32669	0.02437	0.31152	0.03954
34	40.82	0.36170	0.32918	0.03252	0.31382	0.04789
35	40.92	0.37234	0.33670	0.03564	0.32074	0.05160
36	41.03	0.38298	0.34552	0.03746	0.32890	0.05408
37	41.12	0.39362	0.35186	0.04176	0.33478	0.05884
38	41.20	0.40426	0.35823	0.04603	0.34070	0.06355
39	41.22	0.41489	0.35951	0.05539	0.34189	0.07300
40	41.42	0.42553	0.37491	0.05062	0.35628	0.06926
41	41.43	0.43617	0.37620	0.05997	0.35748	0.07869
42	41.57	0.44681	0.38655	0.06026	0.36720	0.07961
43	41.70	0.45745	0.39694	0.06051	0.37701	0.08044
44	41.83	0.46809	0.40737	0.06071	0.38689	0.08120
45	42.12	0.47872	0.42965	0.04908	0.40813	0.07060
46	42.27	0.48936	0.44147	0.04789	0.41949	0.06987

47	42.30	0.50000	0.44410	0.05590	0.42202	0.07798
48	42.42	0.51064	0.45331	0.05733	0.43091	0.07972
49	42.52	0.52128	0.46120	0.06008	0.43856	0.08271
50	42.52	0.53191	0.46120	0.07072	0.43856	0.09335
51	42.68	0.54255	0.47434	0.06821	0.45137	0.09119
52	42.70	0.55319	0.47565	0.07754	0.45265	0.10054
53	42.73	0.56383	0.47828	0.08555	0.45522	0.10861
54	43.07	0.57447	0.50446	0.07001	0.48098	0.09349
55	43.17	0.58511	0.51227	0.07283	0.48873	0.09638
56	43.17	0.59574	0.51227	0.08347	0.48873	0.10702
57	43.22	0.60638	0.51617	0.09021	0.49260	0.11378
58	43.25	0.61702	0.51877	0.09825	0.49519	0.12183
59	43.28	0.62766	0.52136	0.10630	0.49777	0.12989
60	43.53	0.63830	0.54071	0.09758	0.51715	0.12114
61	43.75	0.64894	0.55732	0.09162	0.53392	0.11502
62	43.83	0.65957	0.56366	0.09591	0.54035	0.11922
63	43.92	0.67021	0.56997	0.10024	0.54678	0.12343
64	44.17	0.68085	0.58872	0.09213	0.56597	0.11488
65	44.50	0.69149	0.61324	0.07824	0.59131	0.10018
66	44.55	0.70213	0.61687	0.08526	0.59508	0.10705
67	45.28	0.71277	0.66830	0.04447	0.64921	0.06356
68	45.37	0.72340	0.67391	0.04949	0.65519	0.06821
69	45.45	0.73404	0.67948	0.05456	0.66114	0.07290
70	45.50	0.74468	0.68280	0.06188	0.66469	0.07999
71	45.63	0.75532	0.69156	0.06376	0.67408	0.08124
72	46.28	0.76596	0.73229	0.03367	0.71822	0.04774
73	46.50	0.77660	0.74512	0.03147	0.73227	0.04433
74	46.80	0.78723	0.76225	0.02499	0.75111	0.03612
75	46.88	0.79787	0.76687	0.03100	0.75622	0.04165
76	47.25	0.80851	0.78652	0.02199	0.77800	0.03051
77	47.40	0.81915	0.79423	0.02492	0.78658	0.03256
78	47.45	0.82979	0.79676	0.03303	0.78940	0.04039
79	47.50	0.84043	0.79926	0.04116	0.79220	0.04823
80	47.57	0.85106	0.80257	0.04849	0.79589	0.05518
81	48.00	0.86170	0.82315	0.03855	0.81892	0.04278
82	49.20	0.87234	0.87204	0.00030	0.87380	0.00145
83	49.35	0.88298	0.87734	0.00564	0.87974	0.00324
84	50.23	0.89362	0.90519	0.01157	0.91075	0.01713
85	50.50	0.90426	0.91252	0.00826	0.91883	0.01457
86	50.97	0.91489	0.92423	0.00934	0.93161	0.01672
87	51.00	0.92553	0.92502	0.00051	0.93247	0.00693
88	51.93	0.93617	0.94441	0.00824	0.95311	0.01694
89	52.75	0.94681	0.95771	0.01090	0.96672	0.01991
90	53.60	0.95745	0.96854	0.01109	0.97724	0.01979
91	54.70	0.96809	0.97889	0.01081	0.98657	0.01849
92	54.80	0.97872	0.97966	0.00094	0.98723	0.00850
93	59.23	0.98936	0.99658	0.00721	0.99902	0.00965
94	62.47	1.00000	0.99919	0.00081	0.99990	0.00010
		maximum deviation		0.10630		0.12989
		D(95%) for N =194		0.14027		

County Knox LOAD Road & Drainage 11/24/98
Contract 4123
mean = 2.35 stand. dev= 0.40 # samples 100 zi= 0.17092 lambda= 0.83818

order	Time	nondelay cum. freq.	lognormal cum. prob.	deviation	Normal cum. prob.	deviation
1	0.95	0.01000	0.00000	0.01000	0.00027	0.00973
2	1.33	0.02000	0.00064	0.01936	0.00608	0.01392
3	1.62	0.03000	0.01816	0.01184	0.03547	0.00547
4	1.68	0.04000	0.03166	0.00834	0.05042	0.01042
5	1.77	0.05000	0.05771	0.00771	0.07571	0.02571
6	1.82	0.06000	0.07912	0.01912	0.09497	0.03497
7	1.83	0.07000	0.08730	0.01730	0.10213	0.03213
8	1.83	0.08000	0.08730	0.00730	0.10213	0.02213
9	1.83	0.09000	0.08730	0.00270	0.10213	0.01213
10	1.87	0.10000	0.10526	0.00526	0.11762	0.01762
11	1.92	0.11000	0.13621	0.02621	0.14384	0.03384
12	1.95	0.12000	0.15948	0.03948	0.16337	0.04337
13	1.95	0.13000	0.15948	0.02948	0.16337	0.03337
14	1.97	0.14000	0.17186	0.03186	0.17375	0.03375
15	1.97	0.15000	0.17186	0.02186	0.17375	0.02375
16	1.97	0.16000	0.17186	0.01186	0.17375	0.01375
17	1.97	0.17000	0.17186	0.00186	0.17375	0.00375
18	2.00	0.18000	0.19808	0.01808	0.19574	0.01574
19	2.00	0.19000	0.19808	0.00808	0.19574	0.00574
20	2.00	0.20000	0.19808	0.00192	0.19574	0.00426
21	2.02	0.21000	0.21187	0.00187	0.20735	0.00265
22	2.03	0.22000	0.22609	0.00609	0.21934	0.00066
23	2.03	0.23000	0.22609	0.00391	0.21934	0.01066
24	2.03	0.24000	0.22609	0.01391	0.21934	0.02066
25	2.05	0.25000	0.24071	0.00929	0.23173	0.01827
26	2.08	0.26000	0.27104	0.01104	0.25764	0.00236
27	2.10	0.27000	0.28670	0.01670	0.27114	0.00114
28	2.10	0.28000	0.28670	0.00670	0.27114	0.00886
29	2.12	0.29000	0.30265	0.01265	0.28498	0.00502
30	2.13	0.30000	0.31885	0.01885	0.29914	0.00086
31	2.15	0.31000	0.33528	0.02528	0.31362	0.00362
32	2.17	0.32000	0.35190	0.03190	0.32840	0.00840
33	2.20	0.33000	0.38557	0.05557	0.35874	0.02874
34	2.20	0.34000	0.38557	0.04557	0.35874	0.01874
35	2.22	0.35000	0.40256	0.05256	0.37427	0.02427
36	2.22	0.36000	0.40256	0.04256	0.37427	0.01427
37	2.23	0.37000	0.41961	0.04961	0.39000	0.02000
38	2.23	0.38000	0.41961	0.03961	0.39000	0.01000
39	2.23	0.39000	0.41961	0.02961	0.39000	0.00000
40	2.23	0.40000	0.41961	0.01961	0.39000	0.01000
41	2.25	0.41000	0.43668	0.02668	0.40592	0.00408
42	2.27	0.42000	0.45374	0.03374	0.42199	0.00199
43	2.28	0.43000	0.47076	0.04076	0.43820	0.00820
44	2.28	0.44000	0.47076	0.03076	0.43820	0.00180
45	2.30	0.45000	0.48771	0.03771	0.45451	0.00451
46	2.32	0.46000	0.50456	0.04456	0.47089	0.01089
47	2.32	0.47000	0.50456	0.03456	0.47089	0.00089
48	2.32	0.48000	0.50456	0.02456	0.47089	0.00911

49	2.33	0.49000	0.52128	0.03128	0.48733	0.00267
50	2.33	0.50000	0.52128	0.02128	0.48733	0.01267
51	2.33	0.51000	0.52128	0.01128	0.48733	0.02267
52	2.35	0.52000	0.53785	0.01785	0.50379	0.01621
53	2.38	0.53000	0.57041	0.04041	0.53665	0.00665
54	2.38	0.54000	0.57041	0.03041	0.53665	0.00335
55	2.42	0.55000	0.60206	0.05206	0.56927	0.01927
56	2.42	0.56000	0.60206	0.04206	0.56927	0.00927
57	2.43	0.57000	0.61749	0.04749	0.58542	0.01542
58	2.43	0.58000	0.61749	0.03749	0.58542	0.00542
59	2.45	0.59000	0.63263	0.04263	0.60142	0.01142
60	2.47	0.60000	0.64747	0.04747	0.61726	0.01726
61	2.47	0.61000	0.64747	0.03747	0.61726	0.00726
62	2.47	0.62000	0.64747	0.02747	0.61726	0.00274
63	2.47	0.63000	0.64747	0.01747	0.61726	0.01274
64	2.47	0.64000	0.64747	0.00747	0.61726	0.02274
65	2.47	0.65000	0.64747	0.00253	0.61726	0.03274
66	2.50	0.66000	0.67617	0.01617	0.64833	0.01167
67	2.52	0.67000	0.69001	0.02001	0.66351	0.00649
68	2.53	0.68000	0.70351	0.02351	0.67843	0.00157
69	2.55	0.69000	0.71664	0.02664	0.69307	0.00307
70	2.55	0.70000	0.71664	0.01664	0.69307	0.00693
71	2.55	0.71000	0.71664	0.00664	0.69307	0.01693
72	2.55	0.72000	0.71664	0.00336	0.69307	0.02693
73	2.57	0.73000	0.72940	0.00060	0.70741	0.02259
74	2.57	0.74000	0.72940	0.01060	0.70741	0.03259
75	2.57	0.75000	0.72940	0.02060	0.70741	0.04259
76	2.57	0.76000	0.72940	0.03060	0.70741	0.05259
77	2.60	0.77000	0.75380	0.01620	0.73511	0.03489
78	2.62	0.78000	0.76543	0.01457	0.74845	0.03155
79	2.63	0.79000	0.77667	0.01333	0.76142	0.02858
80	2.63	0.80000	0.77667	0.02333	0.76142	0.03858
81	2.65	0.81000	0.78754	0.02246	0.77401	0.03599
82	2.67	0.82000	0.79803	0.02197	0.78622	0.03378
83	2.67	0.83000	0.79803	0.03197	0.78622	0.04378
84	2.67	0.84000	0.79803	0.04197	0.78622	0.05378
85	2.68	0.85000	0.80814	0.04186	0.79804	0.05196
86	2.70	0.86000	0.81787	0.04213	0.80946	0.05054
87	2.72	0.87000	0.82723	0.04277	0.82047	0.04953
88	2.75	0.88000	0.84486	0.03514	0.84127	0.03873
89	2.75	0.89000	0.84486	0.04514	0.84127	0.04873
90	2.75	0.90000	0.84486	0.05514	0.84127	0.05873
91	2.87	0.91000	0.89575	0.01425	0.90121	0.00879
92	2.88	0.92000	0.90176	0.01824	0.90820	0.01180
93	2.90	0.93000	0.90747	0.02253	0.91481	0.01519
94	2.92	0.94000	0.91291	0.02709	0.92106	0.01894
95	2.93	0.95000	0.91807	0.03193	0.92696	0.02304
96	2.98	0.96000	0.93203	0.02797	0.94264	0.01736
97	3.02	0.97000	0.94016	0.02984	0.95152	0.01848
98	3.20	0.98000	0.97137	0.00863	0.98273	0.00273
99	3.22	0.99000	0.97330	0.01670	0.98442	0.00558
100	3.80	1.00000	0.99817	0.00183	0.99984	0.00016
		maximum deviation		0.05557		0.05873
		D(95%) for N =100		0.13600		

County	Knox		Reposition		Road & Drainage		11/24/98	
Contract	4123							
mean =	1.40		stand. dev=	0.93	# samples 96		zi=	lambda=
							0.60588	0.15131

order	Time	nondelay cum. freq.	lognormal cum. prob.	deviation	Normal cum. prob.	deviation
1	0.33	0.01042	0.01956	0.00914	0.12643	0.11601
2	0.42	0.02083	0.04507	0.02423	0.14596	0.12512
3	0.47	0.03125	0.06582	0.03457	0.15860	0.12735
4	0.50	0.04167	0.08169	0.04003	0.16742	0.12575
5	0.52	0.05208	0.09018	0.03810	0.17195	0.11986
6	0.57	0.06250	0.11758	0.05508	0.18598	0.12348
7	0.58	0.07292	0.12728	0.05436	0.19082	0.11790
8	0.58	0.08333	0.12728	0.04395	0.19082	0.10748
9	0.62	0.09375	0.14741	0.05366	0.20071	0.10696
10	0.63	0.10417	0.15778	0.05362	0.20577	0.10161
11	0.65	0.11458	0.16834	0.05376	0.21091	0.09633
12	0.67	0.12500	0.17906	0.05406	0.21612	0.09112
13	0.70	0.13542	0.20090	0.06548	0.22676	0.09134
14	0.70	0.14583	0.20090	0.05506	0.22676	0.08093
15	0.70	0.15625	0.20090	0.04465	0.22676	0.07051
16	0.70	0.16667	0.20090	0.03423	0.22676	0.06009
17	0.70	0.17708	0.20090	0.02381	0.22676	0.04968
18	0.70	0.18750	0.20090	0.01340	0.22676	0.03926
19	0.72	0.19792	0.21198	0.01406	0.23219	0.03427
20	0.72	0.20833	0.21198	0.00364	0.23219	0.02386
21	0.75	0.21875	0.23436	0.01561	0.24326	0.02451
22	0.77	0.22917	0.24564	0.01647	0.24891	0.01974
23	0.77	0.23958	0.24564	0.00606	0.24891	0.00932
24	0.78	0.25000	0.25695	0.00695	0.25462	0.00462
25	0.82	0.26042	0.27961	0.01919	0.26624	0.00582
26	0.82	0.27083	0.27961	0.00878	0.26624	0.00459
27	0.82	0.28125	0.27961	0.00164	0.26624	0.01501
28	0.83	0.29167	0.29094	0.00073	0.27215	0.01952
29	0.83	0.30208	0.29094	0.01115	0.27215	0.02993
30	0.85	0.31250	0.30224	0.01026	0.27813	0.03437
31	0.87	0.32292	0.31351	0.00941	0.28417	0.03875
32	0.88	0.33333	0.32474	0.00859	0.29027	0.04307
33	0.88	0.34375	0.32474	0.01901	0.29027	0.05348
34	0.90	0.35417	0.33592	0.01825	0.29643	0.05774
35	0.95	0.36458	0.36904	0.00446	0.31526	0.04932
36	0.97	0.37500	0.37992	0.00492	0.32165	0.05335
37	0.98	0.38542	0.39071	0.00529	0.32809	0.05732
38	1.00	0.39583	0.40140	0.00556	0.33459	0.06124
39	1.00	0.40625	0.40140	0.00485	0.33459	0.07166
40	1.00	0.41667	0.40140	0.01527	0.33459	0.08208
41	1.00	0.42708	0.40140	0.02569	0.33459	0.09249
42	1.00	0.43750	0.40140	0.03610	0.33459	0.10291
43	1.02	0.44792	0.41198	0.03594	0.34113	0.10678
44	1.02	0.45833	0.41198	0.04635	0.34113	0.11720
45	1.07	0.46875	0.44306	0.02569	0.36105	0.10770
46	1.07	0.47917	0.44306	0.03611	0.36105	0.11812
47	1.08	0.48958	0.45318	0.03640	0.36777	0.12181

48	1.10	0.50000	0.46318	0.03682	0.37454	0.12546
49	1.10	0.51042	0.46318	0.04724	0.37454	0.13588
50	1.10	0.52083	0.46318	0.05765	0.37454	0.14629
51	1.12	0.53125	0.47305	0.05820	0.38135	0.14990
52	1.13	0.54167	0.48279	0.05888	0.38819	0.15348
53	1.15	0.55208	0.49240	0.05969	0.39507	0.15702
54	1.15	0.56250	0.49240	0.07010	0.39507	0.16743
55	1.17	0.57292	0.50187	0.07105	0.40198	0.17094
56	1.17	0.58333	0.50187	0.08146	0.40198	0.18136
57	1.18	0.59375	0.51121	0.08254	0.40892	0.18483
58	1.27	0.60417	0.55584	0.04833	0.44401	0.16016
59	1.28	0.61458	0.56434	0.05024	0.45109	0.16349
60	1.30	0.62500	0.57272	0.05228	0.45819	0.16681
61	1.32	0.63542	0.58095	0.05447	0.46530	0.17012
62	1.32	0.64583	0.58095	0.06489	0.46530	0.18054
63	1.37	0.65625	0.60482	0.05143	0.48668	0.16957
64	1.37	0.66667	0.60482	0.06185	0.48668	0.17998
65	1.38	0.67708	0.61250	0.06458	0.49382	0.18326
66	1.38	0.68750	0.61250	0.07500	0.49382	0.19368
67	1.38	0.69792	0.61250	0.08542	0.49382	0.20409
68	1.40	0.70833	0.62005	0.08829	0.50097	0.20737
69	1.40	0.71875	0.62005	0.09870	0.50097	0.21778
70	1.45	0.72917	0.64189	0.08727	0.52238	0.20678
71	1.47	0.73958	0.64891	0.09067	0.52951	0.21007
72	1.48	0.75000	0.65580	0.09420	0.53663	0.21337
73	1.50	0.76042	0.66257	0.09785	0.54374	0.21668
74	1.58	0.77083	0.69452	0.07631	0.57901	0.19182
75	1.75	0.78125	0.74981	0.03144	0.64744	0.13381
76	1.77	0.79167	0.75476	0.03691	0.65407	0.13760
77	1.83	0.80208	0.77358	0.02851	0.68008	0.12200
78	1.88	0.81250	0.78672	0.02578	0.69904	0.11346
79	1.95	0.82292	0.80303	0.01988	0.72350	0.09942
80	2.00	0.83333	0.81442	0.01892	0.74118	0.09216
81	2.03	0.84375	0.82162	0.02213	0.75263	0.09112
82	2.17	0.85417	0.84765	0.00652	0.79560	0.05856
83	2.20	0.86458	0.85351	0.01108	0.80561	0.05897
84	2.47	0.87500	0.89259	0.01759	0.87458	0.00042
85	2.62	0.88542	0.90953	0.02411	0.90481	0.01939
86	2.82	0.89583	0.92778	0.03194	0.93628	0.04045
87	2.87	0.90625	0.93169	0.02544	0.94272	0.03647
88	2.98	0.91667	0.93994	0.02328	0.95575	0.03908
89	3.07	0.92708	0.94518	0.01809	0.96350	0.03642
90	3.68	0.93750	0.97143	0.03393	0.99296	0.05546
91	3.77	0.94792	0.97376	0.02584	0.99453	0.04662
92	3.83	0.95833	0.97547	0.01714	0.99556	0.03722
93	3.97	0.96875	0.97854	0.00979	0.99711	0.02836
94	4.03	0.97917	0.97992	0.00075	0.99768	0.01852
95	4.25	0.98958	0.98376	0.00583	0.99891	0.00932
96	4.35	1.00000	0.98525	0.01475	0.99924	0.00076
		maximum deviation		0.09870		0.21778
		D(95%) for N =96		0.13880		

County	Claiborne		End to Arrival		Road & Drainage		11/24/98	
Contract	4615-1							
mean =	6.55		stand. dev=	0.56	# samples	75	zi=	lambda=
							0.08573	1.87650
		nondelay	**lognormal**		**Normal**			
order	Time	cum. freq.	cum. prob.	deviation	cum. prob.	deviation		
1	4.85	0.01333	0.00026	0.01307	0.00123	0.01210		
2	5.35	0.02667	0.01001	0.01666	0.01618	0.01049		
3	5.55	0.04000	0.02885	0.01115	0.03716	0.00284		
4	5.60	0.05333	0.03646	0.01687	0.04496	0.00838		
5	5.68	0.06667	0.05251	0.01416	0.06083	0.00583		
6	5.77	0.08000	0.07336	0.00664	0.08079	0.00079		
7	5.78	0.09333	0.07816	0.01517	0.08531	0.00802		
8	5.78	0.10667	0.07816	0.02851	0.08531	0.02135		
9	5.82	0.12000	0.08842	0.03158	0.09493	0.02507		
10	5.92	0.13333	0.12473	0.00861	0.12854	0.00480		
11	5.98	0.14667	0.15363	0.00697	0.15508	0.00841		
12	6.02	0.16000	0.16949	0.00949	0.16961	0.00961		
13	6.02	0.17333	0.16949	0.00384	0.16961	0.00372		
14	6.03	0.18667	0.17777	0.00890	0.17720	0.00947		
15	6.13	0.20000	0.23204	0.03204	0.22709	0.02709		
16	6.18	0.21333	0.26192	0.04859	0.25475	0.04141		
17	6.18	0.22667	0.26192	0.03525	0.25475	0.02808		
18	6.22	0.24000	0.28274	0.04274	0.27411	0.03411		
19	6.22	0.25333	0.28274	0.02941	0.27411	0.02078		
20	6.25	0.26667	0.30421	0.03754	0.29418	0.02752		
21	6.25	0.28000	0.30421	0.02421	0.29418	0.01418		
22	6.30	0.29333	0.33746	0.04413	0.32550	0.03216		
23	6.30	0.30667	0.33746	0.03080	0.32550	0.01883		
24	6.32	0.32000	0.34880	0.02880	0.33623	0.01623		
25	6.32	0.33333	0.34880	0.01546	0.33623	0.00289		
26	6.37	0.34667	0.38338	0.03672	0.36920	0.02254		
27	6.38	0.36000	0.39508	0.03508	0.38043	0.02043		
28	6.40	0.37333	0.40684	0.03350	0.39176	0.01842		
29	6.42	0.38667	0.41865	0.03198	0.40317	0.01651		
30	6.43	0.40000	0.43050	0.03050	0.41468	0.01468		
31	6.45	0.41333	0.44239	0.02906	0.42625	0.01292		
32	6.45	0.42667	0.44239	0.01572	0.42625	0.00042		
33	6.45	0.44000	0.44239	0.00239	0.42625	0.01375		
34	6.48	0.45333	0.46622	0.01288	0.44958	0.00375		
35	6.50	0.46667	0.47814	0.01147	0.46132	0.00535		
36	6.50	0.48000	0.47814	0.00186	0.46132	0.01868		
37	6.50	0.49333	0.47814	0.01520	0.46132	0.03201		
38	6.53	0.50667	0.50193	0.00474	0.48489	0.02178		
39	6.53	0.52000	0.50193	0.01807	0.48489	0.03511		
40	6.53	0.53333	0.50193	0.03140	0.48489	0.04845		
41	6.55	0.54667	0.51378	0.03288	0.49669	0.04997		
42	6.60	0.56000	0.54905	0.01095	0.53209	0.02791		
43	6.63	0.57333	0.57222	0.00111	0.55557	0.01777		
44	6.72	0.58667	0.62842	0.04175	0.61324	0.02657		

45	6.72	0.60000	0.62842	0.02842	0.61324	0.01324
46	6.72	0.61333	0.62842	0.01508	0.61324	0.00009
47	6.72	0.62667	0.62842	0.00175	0.61324	0.01343
48	6.78	0.64000	0.67107	0.03107	0.65770	0.01770
49	6.78	0.65333	0.67107	0.01774	0.65770	0.00437
50	6.80	0.66667	0.68136	0.01469	0.66851	0.00184
51	6.82	0.68000	0.69148	0.01148	0.67918	0.00082
52	6.87	0.69333	0.72083	0.02750	0.71029	0.01696
53	6.87	0.70667	0.72083	0.01416	0.71029	0.00362
54	6.87	0.72000	0.72083	0.00083	0.71029	0.00971
55	6.88	0.73333	0.73025	0.00308	0.72034	0.01300
56	6.92	0.74667	0.74855	0.00188	0.73990	0.00676
57	6.93	0.76000	0.75741	0.00259	0.74942	0.01058
58	6.93	0.77333	0.75741	0.01592	0.74942	0.02392
59	6.95	0.78667	0.76609	0.02058	0.75874	0.02792
60	6.97	0.80000	0.77456	0.02544	0.76788	0.03212
61	7.00	0.81333	0.79093	0.02241	0.78555	0.02778
62	7.02	0.82667	0.79881	0.02786	0.79409	0.03258
63	7.07	0.84000	0.82127	0.01873	0.81846	0.02154
64	7.13	0.85333	0.84843	0.00490	0.84801	0.00532
65	7.15	0.86667	0.85474	0.01193	0.85487	0.01180
66	7.18	0.88000	0.86676	0.01324	0.86795	0.01205
67	7.22	0.89333	0.87804	0.01530	0.88020	0.01314
68	7.23	0.90667	0.88340	0.02327	0.88601	0.02066
69	7.38	0.92000	0.92387	0.00387	0.92949	0.00949
70	7.38	0.93333	0.92387	0.00947	0.92949	0.00384
71	7.45	0.94667	0.93778	0.00889	0.94413	0.00253
72	7.50	0.96000	0.94678	0.01322	0.95345	0.00655
73	7.68	0.97333	0.97103	0.00230	0.97752	0.00418
74	7.68	0.98667	0.97103	0.01564	0.97752	0.00915
75	7.75	1.00000	0.97708	0.02292	0.98314	0.01686

maximum deviation	0.04859		0.04997
D(95%) for N =75	0.15704		

County	Claiborne	LOAD		Road & Drainage		######	
	Contact 4615-1						
mean =	2.10	stand. dev=	0.22	# samples 85		zi=	lambda=
						0.10562	0.73402

		nondelay	**lognormal**		**Normal**	
order	Time	cum. freq.	cum. prob.	deviation	cum. prob.	deviation
1	1.63	0.01176	0.01060	0.00117	0.01872	0.00695
2	1.70	0.02353	0.02707	0.00354	0.03749	0.01396
3	1.73	0.03529	0.04076	0.00547	0.05152	0.01622
4	1.73	0.04706	0.04076	0.00630	0.05152	0.00446
5	1.78	0.05882	0.07042	0.01160	0.08001	0.02119
6	1.80	0.07059	0.08309	0.01250	0.09178	0.02119
7	1.82	0.08235	0.09726	0.01491	0.10478	0.02243
8	1.82	0.09412	0.09726	0.00314	0.10478	0.01066
9	1.83	0.10588	0.11298	0.00709	0.11907	0.01318
10	1.83	0.11765	0.11298	0.00467	0.11907	0.00142
11	1.85	0.12941	0.13026	0.00085	0.13468	0.00526
12	1.85	0.14118	0.13026	0.01092	0.13468	0.00650
13	1.87	0.15294	0.14911	0.00383	0.15163	0.00131
14	1.87	0.16471	0.14911	0.01559	0.15163	0.01307
15	1.88	0.17647	0.16951	0.00696	0.16996	0.00651
16	1.90	0.18824	0.19142	0.00319	0.18964	0.00140
17	1.93	0.20000	0.23947	0.03947	0.23300	0.03300
18	1.95	0.21176	0.26542	0.05365	0.25659	0.04482
19	1.95	0.22353	0.26542	0.04189	0.25659	0.03306
20	1.95	0.23529	0.26542	0.03012	0.25659	0.02129
21	1.95	0.24706	0.26542	0.01836	0.25659	0.00953
22	1.97	0.25882	0.29248	0.03366	0.28137	0.02254
23	1.97	0.27059	0.29248	0.02189	0.28137	0.01078
24	1.97	0.28235	0.29248	0.01013	0.28137	0.00099
25	1.97	0.29412	0.29248	0.00164	0.28137	0.01275
26	1.97	0.30588	0.29248	0.01340	0.28137	0.02452
27	2.00	0.31765	0.34937	0.03172	0.33412	0.01647
28	2.02	0.32941	0.37887	0.04946	0.36187	0.03246
29	2.02	0.34118	0.37887	0.03770	0.36187	0.02070
30	2.02	0.35294	0.37887	0.02593	0.36187	0.00893
31	2.02	0.36471	0.37887	0.01417	0.36187	0.00283
32	2.02	0.37647	0.37887	0.00240	0.36187	0.01460
33	2.02	0.38824	0.37887	0.00936	0.36187	0.02636
34	2.02	0.40000	0.37887	0.02113	0.36187	0.03813
35	2.02	0.41176	0.37887	0.03289	0.36187	0.04989
36	2.02	0.42353	0.37887	0.04466	0.36187	0.06166
37	2.03	0.43529	0.40885	0.02645	0.39037	0.04492
38	2.03	0.44706	0.40885	0.03821	0.39037	0.05669
39	2.05	0.45882	0.43911	0.01971	0.41947	0.03935
40	2.05	0.47059	0.43911	0.03148	0.41947	0.05111
41	2.05	0.48235	0.43911	0.04324	0.41947	0.06288
42	2.05	0.49412	0.43911	0.05501	0.41947	0.07464
43	2.07	0.50588	0.46949	0.03639	0.44902	0.05686
44	2.07	0.51765	0.46949	0.04816	0.44902	0.06862

45	2.08	0.52941	0.49980	0.02961	0.47886	0.05055
46	2.08	0.54118	0.49980	0.04138	0.47886	0.06232
47	2.10	0.55294	0.52987	0.02307	0.50881	0.04413
48	2.10	0.56471	0.52987	0.03484	0.50881	0.05589
49	2.12	0.57647	0.55953	0.01694	0.53872	0.03775
50	2.12	0.58824	0.55953	0.02870	0.53872	0.04952
51	2.12	0.60000	0.55953	0.04047	0.53872	0.06128
52	2.12	0.61176	0.55953	0.05223	0.53872	0.07305
53	2.13	0.62353	0.58864	0.03489	0.56840	0.05513
54	2.15	0.63529	0.61704	0.01825	0.59771	0.03759
55	2.15	0.64706	0.61704	0.03002	0.59771	0.04935
56	2.15	0.65882	0.61704	0.04178	0.59771	0.06111
57	2.17	0.67059	0.64462	0.02597	0.62647	0.04411
58	2.17	0.68235	0.64462	0.03773	0.62647	0.05588
59	2.17	0.69412	0.64462	0.04950	0.62647	0.06764
60	2.17	0.70588	0.64462	0.06126	0.62647	0.07941
61	2.17	0.71765	0.64462	0.07303	0.62647	0.09117
62	2.18	0.72941	0.67126	0.05815	0.65455	0.07486
63	2.18	0.74118	0.67126	0.06992	0.65455	0.08662
64	2.18	0.75294	0.67126	0.08168	0.65455	0.09839
65	2.22	0.76471	0.72135	0.04336	0.70811	0.05660
66	2.22	0.77647	0.72135	0.05512	0.70811	0.06836
67	2.23	0.78824	0.74466	0.04358	0.73335	0.05489
68	2.25	0.80000	0.76675	0.03325	0.75744	0.04256
69	2.25	0.81176	0.76675	0.04502	0.75744	0.05433
70	2.27	0.82353	0.78758	0.03595	0.78030	0.04323
71	2.28	0.83529	0.80714	0.02815	0.80186	0.03343
72	2.33	0.84706	0.85825	0.01119	0.85851	0.01145
73	2.35	0.85882	0.87283	0.01401	0.87467	0.01584
74	2.35	0.87059	0.87283	0.00225	0.87467	0.00408
75	2.35	0.88235	0.87283	0.00952	0.87467	0.00768
76	2.35	0.89412	0.87283	0.02128	0.87467	0.01945
77	2.38	0.90588	0.89854	0.00735	0.90302	0.00286
78	2.38	0.91765	0.89854	0.01911	0.90302	0.01463
79	2.42	0.92941	0.91995	0.00946	0.92636	0.00306
80	2.52	0.94118	0.96316	0.02199	0.97127	0.03010
81	2.53	0.95294	0.96793	0.01498	0.97586	0.02292
82	2.53	0.96471	0.96793	0.00322	0.97586	0.01116
83	2.57	0.97647	0.97586	0.00061	0.98321	0.00674
84	2.65	0.98824	0.98862	0.00038	0.99380	0.00557
85	2.83	1.00000	0.99820	0.00180	0.99956	0.00044
		maximum deviation		0.08168		0.09839
		D(95%) for N =85		0.14751		

County	Claiborne		Reposition		Road & Drainage		11/24/98	
Contract	4615-1							
mean =	0.64		stand. dev=	0.08	# samples	68	zi=	lambda=
							0.12432	-0.46062

		nondelay	lognormal		Normal	
order	Time	cum. freq.	cum. prob.	deviation	cum. prob.	deviation
1	0.27	0.01471	0.00000	0.01471	0.00000	0.01470
2	0.52	0.02941	0.05407	0.02465	0.06665	0.03723
3	0.53	0.04412	0.08831	0.04419	0.09832	0.05420
4	0.53	0.05882	0.08831	0.02948	0.09832	0.03949
5	0.53	0.07353	0.08831	0.01478	0.09832	0.02479
6	0.55	0.08824	0.13485	0.04662	0.13982	0.05158
7	0.57	0.10294	0.19390	0.09096	0.19185	0.08891
8	0.57	0.11765	0.19390	0.07626	0.19185	0.07420
9	0.57	0.13235	0.19390	0.06155	0.19185	0.05950
10	0.58	0.14706	0.26421	0.11715	0.25429	0.10723
11	0.58	0.16176	0.26421	0.10244	0.25429	0.09253
12	0.58	0.17647	0.26421	0.08774	0.25429	0.07782
13	0.58	0.19118	0.26421	0.07303	0.25429	0.06312
14	0.58	0.20588	0.26421	0.05833	0.25429	0.04841
15	0.58	0.22059	0.26421	0.04362	0.25429	0.03370
16	0.58	0.23529	0.26421	0.02891	0.25429	0.01900
17	0.58	0.25000	0.26421	0.01421	0.25429	0.00429
18	0.58	0.26471	0.26421	0.00050	0.25429	0.01041
19	0.60	0.27941	0.34317	0.06376	0.32600	0.04659
20	0.60	0.29412	0.34317	0.04905	0.32600	0.03188
21	0.60	0.30882	0.34317	0.03435	0.32600	0.01717
22	0.60	0.32353	0.34317	0.01964	0.32600	0.00247
23	0.60	0.33824	0.34317	0.00494	0.32600	0.01224
24	0.60	0.35294	0.34317	0.00977	0.32600	0.02694
25	0.62	0.36765	0.42723	0.05958	0.40480	0.03715
26	0.62	0.38235	0.42723	0.04488	0.40480	0.02245
27	0.62	0.39706	0.42723	0.03017	0.40480	0.00774
28	0.62	0.41176	0.42723	0.01547	0.40480	0.00696
29	0.62	0.42647	0.42723	0.00076	0.40480	0.02167
30	0.62	0.44118	0.42723	0.01395	0.40480	0.03638
31	0.63	0.45588	0.51240	0.05652	0.48768	0.03180
32	0.63	0.47059	0.51240	0.04181	0.48768	0.01709
33	0.63	0.48529	0.51240	0.02711	0.48768	0.00238
34	0.63	0.50000	0.51240	0.01240	0.48768	0.01232
35	0.63	0.51471	0.51240	0.00231	0.48768	0.02703
36	0.63	0.52941	0.51240	0.01701	0.48768	0.04173
37	0.63	0.54412	0.51240	0.03172	0.48768	0.05644
38	0.65	0.55882	0.59485	0.03602	0.57109	0.01227
39	0.65	0.57353	0.59485	0.02132	0.57109	0.00243
40	0.65	0.58824	0.59485	0.00661	0.57109	0.01714
41	0.65	0.60294	0.59485	0.00809	0.57109	0.03185
42	0.65	0.61765	0.59485	0.02280	0.57109	0.04655
43	0.65	0.63235	0.59485	0.03751	0.57109	0.06126
44	0.65	0.64706	0.59485	0.05221	0.57109	0.07596

45	0.67	0.66176	0.67137	0.00960	0.65144	0.01032
46	0.67	0.67647	0.67137	0.00510	0.65144	0.02503
47	0.67	0.69118	0.67137	0.01981	0.65144	0.03974
48	0.67	0.70588	0.67137	0.03452	0.65144	0.05444
49	0.68	0.72059	0.73967	0.01908	0.72550	0.00491
50	0.68	0.73529	0.73967	0.00437	0.72550	0.00979
51	0.68	0.75000	0.73967	0.01033	0.72550	0.02450
52	0.68	0.76471	0.73967	0.02504	0.72550	0.03920
53	0.68	0.77941	0.73967	0.03975	0.72550	0.05391
54	0.68	0.79412	0.73967	0.05445	0.72550	0.06862
55	0.68	0.80882	0.73967	0.06916	0.72550	0.08332
56	0.68	0.82353	0.73967	0.08386	0.72550	0.09803
57	0.68	0.83824	0.73967	0.09857	0.72550	0.11273
58	0.70	0.85294	0.79847	0.05448	0.79083	0.06211
59	0.70	0.86765	0.79847	0.06918	0.79083	0.07681
60	0.72	0.88235	0.84742	0.03493	0.84599	0.03637
61	0.73	0.89706	0.88693	0.01013	0.89054	0.00652
62	0.73	0.91176	0.88693	0.02484	0.89054	0.02122
63	0.75	0.92647	0.91791	0.00856	0.92499	0.00148
64	0.75	0.94118	0.91791	0.02327	0.92499	0.01619
65	0.77	0.95588	0.94155	0.01433	0.95048	0.00540
66	0.80	0.97059	0.97195	0.00136	0.98076	0.01017
67	0.80	0.98529	0.97195	0.01334	0.98076	0.00454
68	0.80	1.00000	0.97195	0.02805	0.98076	0.01924
		maximum deviation		0.11715		0.11273
		D(95%) for N =79		0.16492		

Appendix D

Sample K-S Tests for Borrow Excavation

TRUCK CYCLE

KS TEST BORROW

Contract #: 3502 County: Carroll 11/24/98

Mean	Stand. Dev.	# samples	ζ	λ
15.72	**4.08**	**53.00**	**0.2553**	**2.7223**

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
1	4.45	0.01887	0.00000	0.01887	0.00286	0.01600
2	4.83	0.03774	0.00000	0.03773	0.00380	0.03393
3	12.17	0.05660	0.19056	0.13396	0.19176	0.13515
4	12.33	0.07547	0.20538	0.12991	0.20310	0.12763
5	12.73	0.09434	0.24274	0.14840	0.23192	0.13758
6	12.92	0.11321	0.26059	0.14738	0.24585	0.13265
7	12.98	0.13208	0.26718	0.13511	0.25103	0.11896
8	13.00	0.15094	0.26884	0.11789	0.25233	0.10139
9	13.15	0.16981	0.28386	0.11405	0.26422	0.09441
10	13.25	0.18868	0.29400	0.10532	0.27230	0.08362
11	13.27	0.20755	0.29570	0.08816	0.27365	0.06611
12	13.28	0.22642	0.29740	0.07099	0.27502	0.04860
13	13.30	0.24528	0.29911	0.05382	0.27638	0.03110
14	13.37	0.26415	0.30594	0.04179	0.28187	0.01772
15	13.38	0.28302	0.30766	0.02464	0.28326	0.00024
16	13.40	0.30189	0.30937	0.00749	0.28464	0.01725
17	13.58	0.32075	0.32838	0.00762	0.30008	0.02068
18	13.63	0.33962	0.33359	0.00603	0.30435	0.03527
19	13.70	0.35849	0.34057	0.01792	0.31010	0.04839
20	13.73	0.37736	0.34407	0.03329	0.31299	0.06437
21	13.75	0.39623	0.34582	0.05041	0.31443	0.08179
22	13.80	0.41509	0.35108	0.06402	0.31880	0.09630
23	13.88	0.43396	0.35986	0.07410	0.32613	0.10784
24	13.90	0.45283	0.36162	0.09121	0.32760	0.12523
25	13.97	0.47170	0.36866	0.10303	0.33352	0.13818
26	13.97	0.49057	0.36866	0.12190	0.33352	0.15704
27	14.40	0.50943	0.41461	0.09483	0.37297	0.13646
28	14.63	0.52830	0.43930	0.08901	0.39482	0.13349
29	15.07	0.54717	0.48467	0.06250	0.43622	0.11095
30	15.53	0.56604	0.53229	0.03374	0.48159	0.08445
31	15.57	0.58491	0.53563	0.04928	0.48484	0.10006
32	15.85	0.60377	0.56359	0.04018	0.51254	0.09123
33	15.92	0.62264	0.57006	0.05258	0.51906	0.10358

34	16.47	0.64151	0.62156	0.01995	0.57245	0.06906
35	16.67	0.66038	0.63941	0.02097	0.59159	0.06879
36	16.77	0.67925	0.64814	0.03110	0.60108	0.07816
37	17.27	0.69811	0.68984	0.00827	0.64755	0.05056
38	17.38	0.71698	0.69909	0.01789	0.65811	0.05887
39	17.38	0.73585	0.69909	0.03676	0.65811	0.07774
40	17.85	0.75472	0.73420	0.02052	0.69906	0.05565
41	18.68	0.77358	0.78938	0.01580	0.76607	0.00751
42	18.72	0.79245	0.79139	0.00106	0.76857	0.02388
43	19.35	0.81132	0.82680	0.01548	0.81311	0.00178
44	19.65	0.83019	0.84180	0.01161	0.83221	0.00202
45	19.95	0.84906	0.85570	0.00665	0.85001	0.00095
46	20.03	0.86792	0.85938	0.00854	0.85472	0.01320
47	21.60	0.88679	0.91504	0.02825	0.92520	0.03841
48	21.62	0.90566	0.91551	0.00985	0.92577	0.02011
49	22.00	0.92453	0.92568	0.00115	0.93810	0.01357
50	22.20	0.94340	0.93054	0.01286	0.94386	0.00046
51	22.53	0.96226	0.93800	0.02427	0.95251	0.00975
52	24.53	0.98113	0.96935	0.01179	0.98461	0.00348
53	25.90	1.00000	0.98140	0.01860	0.99370	0.00630

Lognormal Maximum Deviation **0.1484**

Normal Maximum Deviation **0.1570**

Allowable Maximum Deviation

D(95%) for N = 53 **0.1868**

Best Fit : **LOGNORMAL**

PROCESSOR CYCLE

KS TEST BORROW

Contract #: 3502 County: Carroll 11/24/98

Mean	Stand. Dev.	# samples	ζ	λ
1.85	**0.29**	**65.00**	**0.1573**	**0.6024**

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
1	1.37	0.01538	0.03260	0.01721	0.04959	0.03421
2	1.43	0.03077	0.06164	0.03088	0.07765	0.04688
3	1.45	0.04615	0.07110	0.02495	0.08627	0.04011
4	1.45	0.06154	0.07110	0.00957	0.08627	0.02473
5	1.50	0.07692	0.10527	0.02835	0.11638	0.03946
6	1.50	0.09231	0.10527	0.01296	0.11638	0.02408
7	1.50	0.10769	0.10527	0.00242	0.11638	0.00869
8	1.53	0.12308	0.13300	0.00992	0.14021	0.01713
9	1.53	0.13846	0.13300	0.00546	0.14021	0.00175
10	1.57	0.15385	0.16463	0.01078	0.16715	0.01331
11	1.57	0.16923	0.16463	0.00460	0.16715	0.00208
12	1.58	0.18462	0.18185	0.00276	0.18180	0.00282
13	1.58	0.20000	0.18185	0.01815	0.18180	0.01820
14	1.60	0.21538	0.19996	0.01542	0.19722	0.01816
15	1.62	0.23077	0.21891	0.01186	0.21341	0.01736
16	1.63	0.24615	0.23865	0.00751	0.23035	0.01580
17	1.63	0.26154	0.23865	0.02289	0.23035	0.03119
18	1.63	0.27692	0.23865	0.03827	0.23035	0.04657
19	1.67	0.29231	0.28021	0.01210	0.26638	0.02593
20	1.68	0.30769	0.30190	0.00579	0.28541	0.02228
21	1.70	0.32308	0.32408	0.00101	0.30506	0.01802
22	1.70	0.33846	0.32408	0.01438	0.30506	0.03340
23	1.72	0.35385	0.34669	0.00716	0.32529	0.02855
24	1.73	0.36923	0.36962	0.00039	0.34605	0.02318
25	1.73	0.38462	0.36962	0.01499	0.34605	0.03856
26	1.77	0.40000	0.41615	0.01615	0.38893	0.01107
27	1.77	0.41538	0.41615	0.00077	0.38893	0.02645
28	1.78	0.43077	0.43957	0.00880	0.41093	0.01984
29	1.78	0.44615	0.43957	0.00658	0.41093	0.03523
30	1.78	0.46154	0.43957	0.02197	0.41093	0.05061
31	1.78	0.47692	0.43957	0.03735	0.41093	0.06600
32	1.80	0.49231	0.46299	0.02932	0.43321	0.05910
33	1.80	0.50769	0.46299	0.04470	0.43321	0.07448
34	1.82	0.52308	0.48631	0.03676	0.45570	0.06737
35	1.83	0.53846	0.50947	0.02899	0.47834	0.06012

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
36	1.83	0.55385	0.50947	0.04437	0.47834	0.07551
37	1.87	0.56923	0.55500	0.01423	0.52375	0.04548
38	1.87	0.58462	0.55500	0.02961	0.52375	0.06086
39	1.88	0.60000	0.57723	0.02277	0.54638	0.05362
40	1.88	0.61538	0.57723	0.03815	0.54638	0.06900
41	1.90	0.63077	0.59903	0.03174	0.56886	0.06191
42	1.92	0.64615	0.62034	0.02582	0.59112	0.05504
43	1.92	0.66154	0.62034	0.04120	0.59112	0.07042
44	1.93	0.67692	0.64110	0.03582	0.61308	0.06384
45	1.95	0.69231	0.66129	0.03102	0.63469	0.05761
46	1.95	0.70769	0.66129	0.04640	0.63469	0.07300
47	1.98	0.72308	0.69977	0.02330	0.67660	0.04648
48	2.00	0.73846	0.71801	0.02045	0.69678	0.04168
49	2.00	0.75385	0.71801	0.03583	0.69678	0.05707
50	2.03	0.76923	0.75239	0.01684	0.73534	0.03389
51	2.03	0.78462	0.75239	0.03222	0.73534	0.04927
52	2.05	0.80000	0.76851	0.03149	0.75364	0.04636
53	2.07	0.81538	0.78390	0.03149	0.77124	0.04414
54	2.07	0.83077	0.78390	0.04687	0.77124	0.05953
55	2.10	0.84615	0.81250	0.03365	0.80423	0.04192
56	2.12	0.86154	0.82573	0.03581	0.81959	0.04195
57	2.13	0.87692	0.83825	0.03868	0.83416	0.04276
58	2.15	0.89231	0.85007	0.04223	0.84795	0.04436
59	2.17	0.90769	0.86123	0.04647	0.86096	0.04674
60	2.17	0.92308	0.86123	0.06185	0.86096	0.06212
61	2.22	0.93846	0.89082	0.04764	0.89535	0.04312
62	2.43	0.95385	0.96591	0.01206	0.97702	0.02318
63	2.48	0.96923	0.97460	0.00537	0.98487	0.01564
64	2.72	0.98462	0.99420	0.00958	0.99848	0.01387
65	2.85	1.00000	0.99766	0.00234	0.99969	0.00031

	Lognormal Maximum Deviation **0.0619**	Normal Maximum Deviation **0.0755**
D(95%) for N =65	Allowable Maximum Deviation **0.1687**	

Best Fit : **LOGNORMAL**

REPOSITION CYCLE

KS TEST BORROW

Contract #: 3502 County: Carroll 11/24/98

Mean	Stand. Dev.	# samples	ζ	λ
0.98	**0.63**	**63.00**	**0.5873**	**-0.1917**

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
1	0.23	0.01587	0.01572	0.00015	0.11751	0.10164
2	0.27	0.03175	0.02717	0.00458	0.12828	0.09653
3	0.33	0.04762	0.06127	0.01365	0.15182	0.10420
4	0.38	0.06349	0.09574	0.03225	0.17124	0.10775
5	0.40	0.07937	0.10865	0.02928	0.17806	0.09869
6	0.40	0.09524	0.10865	0.01341	0.17806	0.08282
7	0.42	0.11111	0.12216	0.01105	0.18504	0.07393
8	0.42	0.12698	0.12216	0.00482	0.18504	0.05806
9	0.42	0.14286	0.12216	0.02069	0.18504	0.04219
10	0.43	0.15873	0.13622	0.02251	0.19219	0.03346
11	0.45	0.17460	0.15075	0.02385	0.19951	0.02491
12	0.48	0.19048	0.18101	0.00947	0.21464	0.02417
13	0.48	0.20635	0.18101	0.02534	0.21464	0.00829
14	0.50	0.22222	0.19661	0.02562	0.22245	0.00023
15	0.52	0.23810	0.21244	0.02565	0.23042	0.00768
16	0.55	0.25397	0.24462	0.00935	0.24682	0.00715
17	0.55	0.26984	0.24462	0.02522	0.24682	0.02302
18	0.58	0.28571	0.27715	0.00857	0.26383	0.02188
19	0.58	0.30159	0.27715	0.02444	0.26383	0.03776
20	0.62	0.31746	0.30969	0.00777	0.28142	0.03604
21	0.62	0.33333	0.30969	0.02364	0.28142	0.05191
22	0.62	0.34921	0.30969	0.03951	0.28142	0.06779
23	0.65	0.36508	0.34197	0.02311	0.29955	0.06553
24	0.70	0.38095	0.38939	0.00844	0.32770	0.05325
25	0.72	0.39683	0.40484	0.00801	0.33732	0.05951
26	0.73	0.41270	0.42008	0.00738	0.34704	0.06566
27	0.77	0.42857	0.44986	0.02129	0.36679	0.06178
28	0.78	0.44444	0.46439	0.01994	0.37680	0.06765
29	0.85	0.46032	0.51981	0.05949	0.41761	0.04270
30	0.85	0.47619	0.51981	0.04362	0.41761	0.05858
31	0.87	0.49206	0.53297	0.04091	0.42798	0.06409
32	0.88	0.50794	0.54585	0.03791	0.43839	0.06955
33	0.90	0.52381	0.55844	0.03463	0.44884	0.07497
34	0.92	0.53968	0.57074	0.03105	0.45933	0.08035

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
35	0.97	0.55556	0.60591	0.05035	0.49095	0.06461
36	0.97	0.57143	0.60591	0.03448	0.49095	0.08048
37	0.98	0.58730	0.61707	0.02976	0.50151	0.08579
38	1.05	0.60317	0.65890	0.05573	0.54367	0.05951
39	1.10	0.61905	0.68747	0.06842	0.57499	0.04406
40	1.13	0.63492	0.70523	0.07031	0.59563	0.03929
41	1.13	0.65079	0.70523	0.05444	0.59563	0.05517
42	1.15	0.66667	0.71375	0.04708	0.60585	0.06082
43	1.15	0.68254	0.71375	0.03121	0.60585	0.07669
44	1.15	0.69841	0.71375	0.01534	0.60585	0.09256
45	1.17	0.71429	0.72203	0.00774	0.61600	0.09829
46	1.17	0.73016	0.72203	0.00813	0.61600	0.11416
47	1.17	0.74603	0.72203	0.02401	0.61600	0.13003
48	1.17	0.76190	0.72203	0.03988	0.61600	0.14591
49	1.18	0.77778	0.73007	0.04771	0.62607	0.15171
50	1.20	0.79365	0.73788	0.05577	0.63606	0.15760
51	1.22	0.80952	0.74548	0.06405	0.64595	0.16357
52	1.23	0.82540	0.75285	0.07255	0.65575	0.16965
53	1.23	0.84127	0.75285	0.08842	0.65575	0.18552
54	1.23	0.85714	0.75285	0.10429	0.65575	0.20140
55	1.25	0.87302	0.76001	0.11300	0.66544	0.20758
56	1.25	0.88889	0.76001	0.12888	0.66544	0.22345
57	1.33	0.90476	0.79282	0.11195	0.71217	0.19260
58	1.63	0.92063	0.87734	0.04330	0.84996	0.07068
59	2.00	0.93651	0.93404	0.00246	0.94724	0.01073
60	2.45	0.95238	0.96800	0.01562	0.99019	0.03781
61	2.77	0.96825	0.98026	0.01200	0.99772	0.02946
62	3.17	0.98413	0.98896	0.00483	0.99974	0.01561
63	3.33	1.00000	0.99126	0.00874	0.99991	0.00009

Lognormal Maximum Deviation **0.1289**

Normal Maximum Deviation **0.2234**

D(95%) for N =63 — Allowable Maximum Deviation **0.1713**

Best Fit : **LOGNORMAL**

TRUCK CYCLE

KS TEST (Non-Delay) BORROW

Contract #: 4779 County: Obion 11/24/98

Mean	Stand. Dev.	# samples	ζ	λ
7.83	**0.86**	**77.00**	**0.1095**	**2.0520**

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
1	5.53	0.01299	0.00092	0.01207	0.00387	0.00911
2	5.95	0.02597	0.00708	0.01889	0.01461	0.01136
3	6.02	0.03896	0.00935	0.02961	0.01772	0.02124
4	6.12	0.05195	0.01388	0.03807	0.02343	0.02852
5	6.22	0.06494	0.02005	0.04488	0.03062	0.03432
6	6.27	0.07792	0.02388	0.05404	0.03484	0.04308
7	6.32	0.09091	0.02827	0.06264	0.03954	0.05137
8	6.35	0.10390	0.03152	0.07237	0.04295	0.06095
9	6.57	0.11688	0.06028	0.05661	0.07124	0.04564
10	6.70	0.12987	0.08552	0.04435	0.09471	0.03516
11	6.83	0.14286	0.11723	0.02562	0.12345	0.01941
12	6.87	0.15584	0.12621	0.02963	0.13150	0.02434
13	6.93	0.16883	0.14543	0.02340	0.14867	0.02016
14	6.95	0.18182	0.15049	0.03133	0.15319	0.02863
15	7.22	0.19481	0.24495	0.05014	0.23757	0.04276
16	7.33	0.20779	0.29321	0.08542	0.28127	0.07347
17	7.35	0.22078	0.30039	0.07961	0.28781	0.06703
18	7.42	0.23377	0.32967	0.09590	0.31469	0.08092
19	7.43	0.24675	0.33712	0.09037	0.32157	0.07482
20	7.53	0.25974	0.38274	0.12300	0.36409	0.10435
21	7.55	0.27273	0.39047	0.11774	0.37136	0.09863
22	7.55	0.28571	0.39047	0.10475	0.37136	0.08565
23	7.60	0.29870	0.41378	0.11508	0.39344	0.09474
24	7.63	0.31169	0.42942	0.11773	0.40835	0.09666
25	7.63	0.32468	0.42942	0.10474	0.40835	0.08368
26	7.65	0.33766	0.43725	0.09959	0.41586	0.07820
27	7.68	0.35065	0.45294	0.10229	0.43097	0.08032
28	7.70	0.36364	0.46079	0.09715	0.43857	0.07493
29	7.72	0.37662	0.46864	0.09201	0.44618	0.06956
30	7.75	0.38961	0.48431	0.09470	0.46147	0.07186
31	7.77	0.40260	0.49213	0.08954	0.46914	0.06654
32	7.77	0.41558	0.49213	0.07655	0.46914	0.05356
33	7.83	0.42857	0.52326	0.09469	0.49990	0.07133
34	7.85	0.44156	0.53099	0.08943	0.50760	0.06604
35	7.87	0.45455	0.53868	0.08414	0.51529	0.06075
36	7.87	0.46753	0.53868	0.07115	0.51529	0.04776
37	7.90	0.48052	0.55398	0.07346	0.53066	0.05014
38	7.90	0.49351	0.55398	0.06048	0.53066	0.03715
39	7.92	0.50649	0.56158	0.05509	0.53833	0.03183
40	7.92	0.51948	0.56158	0.04210	0.53833	0.01885
41	7.93	0.53247	0.56914	0.03667	0.54598	0.01351
42	7.97	0.54545	0.58413	0.03868	0.56124	0.01578

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
43	8.03	0.55844	0.61355	0.05511	0.59145	0.03301
44	8.05	0.57143	0.62077	0.04934	0.59893	0.02750
45	8.07	0.58442	0.62794	0.04352	0.60637	0.02195
46	8.08	0.59740	0.63504	0.03764	0.61377	0.01637
47	8.08	0.61039	0.63504	0.02466	0.61377	0.00338
48	8.08	0.62338	0.63504	0.01167	0.61377	0.00960
49	8.12	0.63636	0.64908	0.01271	0.62845	0.00791
50	8.12	0.64935	0.64908	0.00027	0.62845	0.02090
51	8.12	0.66234	0.64908	0.01326	0.62845	0.03389
52	8.13	0.67532	0.65600	0.01933	0.63572	0.03960
53	8.17	0.68831	0.66964	0.01867	0.65012	0.03819
54	8.22	0.70130	0.68958	0.01172	0.67131	0.02999
55	8.23	0.71429	0.69608	0.01821	0.67825	0.03603
56	8.23	0.72727	0.69608	0.03119	0.67825	0.04902
57	8.28	0.74026	0.71514	0.02512	0.69871	0.04155
58	8.32	0.75325	0.72745	0.02579	0.71202	0.04123
59	8.32	0.76623	0.72745	0.03878	0.71202	0.05422
60	8.42	0.77922	0.76247	0.01675	0.75018	0.02904
61	8.42	0.79221	0.76247	0.02973	0.75018	0.04203
62	8.45	0.80519	0.77349	0.03171	0.76228	0.04292
63	8.45	0.81818	0.77349	0.04470	0.76228	0.05591
64	8.45	0.83117	0.77349	0.05768	0.76228	0.06889
65	8.58	0.84416	0.81417	0.02999	0.80730	0.03685
66	8.65	0.85714	0.83248	0.02466	0.82772	0.02943
67	8.73	0.87013	0.85350	0.01663	0.85121	0.01892
68	8.83	0.88312	0.87607	0.00705	0.87645	0.00667
69	8.87	0.89610	0.88297	0.01314	0.88415	0.01195
70	8.93	0.90909	0.89587	0.01322	0.89852	0.01057
71	9.00	0.92208	0.90762	0.01446	0.91155	0.01053
72	9.08	0.93506	0.92079	0.01427	0.92603	0.00904
73	9.10	0.94805	0.92323	0.02482	0.92869	0.01936
74	9.17	0.96104	0.93239	0.02865	0.93862	0.02242
75	9.33	0.97403	0.95138	0.02265	0.95874	0.01529
76	9.60	0.98701	0.97229	0.01472	0.97957	0.00744
77	9.62	1.00000	0.97329	0.02671	0.98050	0.01950
				Lognormal Maximum Deviation **0.1230**		Normal Maximum Deviation **0.1043**
			D(95%) for N = 77	Allowable Maximum Deviation **0.1550**		
			Best Fit :	**NORMAL**		

PROCESSOR CYCLE

KS TEST BORROW

Contract #: 4779 County: Obion 11/24/98

Mean	Dev.	# samples	ζ	λ
1.65	**0.34**	**88.00**	**0.2052**	**0.4806**

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
1	1.05	0.01136	0.01768	0.00632	0.03955	0.02818
2	1.15	0.02273	0.04837	0.02564	0.07159	0.04886
3	1.15	0.03409	0.04837	0.01428	0.07159	0.03750
4	1.17	0.04545	0.05583	0.01038	0.07847	0.03302
5	1.17	0.05682	0.05583	0.00099	0.07847	0.02166
6	1.18	0.06818	0.06405	0.00413	0.08585	0.01767
7	1.22	0.07955	0.08283	0.00328	0.10214	0.02260
8	1.23	0.09091	0.09342	0.00251	0.11108	0.02017
9	1.27	0.10227	0.11701	0.01474	0.13062	0.02834
10	1.27	0.11364	0.11701	0.00337	0.13062	0.01698
11	1.32	0.12500	0.15831	0.03331	0.16416	0.03916
12	1.33	0.13636	0.17357	0.03721	0.17648	0.04012
13	1.33	0.14773	0.17357	0.02585	0.17648	0.02875
14	1.33	0.15909	0.17357	0.01448	0.17648	0.01739
15	1.35	0.17045	0.18954	0.01908	0.18937	0.01892
16	1.35	0.18182	0.18954	0.00772	0.18937	0.00756
17	1.35	0.19318	0.18954	0.00365	0.18937	0.00381
18	1.37	0.20455	0.20616	0.00161	0.20283	0.00171
19	1.37	0.21591	0.20616	0.00975	0.20283	0.01308
20	1.38	0.22727	0.22340	0.00387	0.21684	0.01043
21	1.40	0.23864	0.24121	0.00257	0.23140	0.00724
22	1.40	0.25000	0.24121	0.00879	0.23140	0.01860
23	1.42	0.26136	0.25955	0.00182	0.24649	0.01488
24	1.43	0.27273	0.27835	0.00562	0.26208	0.01064
25	1.43	0.28409	0.27835	0.00574	0.26208	0.02201
26	1.43	0.29545	0.27835	0.01711	0.26208	0.03337
27	1.43	0.30682	0.27835	0.02847	0.26208	0.04473
28	1.45	0.31818	0.29756	0.02062	0.27817	0.04001
29	1.48	0.32955	0.33699	0.00745	0.31172	0.01782
30	1.48	0.34091	0.33699	0.00392	0.31172	0.02918
31	1.48	0.35227	0.33699	0.01528	0.31172	0.04055
32	1.48	0.36364	0.33699	0.02665	0.31172	0.05191
33	1.52	0.37500	0.37737	0.00237	0.34692	0.02808
34	1.52	0.38636	0.37737	0.00900	0.34692	0.03945
35	1.53	0.39773	0.39776	0.00003	0.36505	0.03268
36	1.53	0.40909	0.39776	0.01133	0.36505	0.04405
37	1.53	0.42045	0.39776	0.02270	0.36505	0.05541
38	1.55	0.43182	0.41821	0.01361	0.38348	0.04834
39	1.55	0.44318	0.41821	0.02497	0.38348	0.05970
40	1.55	0.45455	0.41821	0.03634	0.38348	0.07106
41	1.57	0.46591	0.43866	0.02725	0.40218	0.06372
42	1.60	0.47727	0.47935	0.00208	0.44023	0.03704
43	1.62	0.48864	0.49948	0.01085	0.45948	0.02915
44	1.62	0.50000	0.49948	0.00052	0.45948	0.04052
45	1.63	0.51136	0.51941	0.00805	0.47883	0.03253
46	1.63	0.52273	0.51941	0.00331	0.47883	0.04389
47	1.65	0.53409	0.53909	0.00500	0.49824	0.03586
48	1.65	0.54545	0.53909	0.00636	0.49824	0.04722

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
49	1.65	0.55682	0.53909	0.01773	0.49824	0.05858
50	1.67	0.56818	0.55848	0.00970	0.51764	0.05054
51	1.67	0.57955	0.55848	0.02107	0.51764	0.06191
52	1.67	0.59091	0.55848	0.03243	0.51764	0.07327
53	1.68	0.60227	0.57754	0.02474	0.53700	0.06527
54	1.70	0.61364	0.59623	0.01741	0.55628	0.05736
55	1.72	0.62500	0.61453	0.01047	0.57542	0.04958
56	1.73	0.63636	0.63240	0.00396	0.59439	0.04197
57	1.73	0.64773	0.63240	0.01533	0.59439	0.05334
58	1.75	0.65909	0.64982	0.00927	0.61314	0.04595
59	1.75	0.67045	0.64982	0.02063	0.61314	0.05732
60	1.77	0.68182	0.66678	0.01504	0.63162	0.05019
61	1.77	0.69318	0.66678	0.02641	0.63162	0.06156
62	1.77	0.70455	0.66678	0.03777	0.63162	0.07292
63	1.77	0.71591	0.66678	0.04913	0.63162	0.08428
64	1.78	0.72727	0.68324	0.04403	0.64981	0.07746
65	1.78	0.73864	0.68324	0.05540	0.64981	0.08882
66	1.78	0.75000	0.68324	0.06676	0.64981	0.10019
67	1.80	0.76136	0.69920	0.06216	0.66766	0.09370
68	1.82	0.77273	0.71465	0.05808	0.68514	0.08759
69	1.83	0.78409	0.72957	0.05452	0.70221	0.08188
70	1.87	0.79545	0.75782	0.03764	0.73503	0.06043
71	1.88	0.80682	0.77114	0.03568	0.75071	0.05610
72	1.95	0.81818	0.81914	0.00096	0.80822	0.00996
73	1.95	0.82955	0.81914	0.01040	0.80822	0.02132
74	1.97	0.84091	0.82985	0.01106	0.82122	0.01969
75	1.98	0.85227	0.84006	0.01222	0.83364	0.01863
76	2.00	0.86364	0.84977	0.01386	0.84550	0.01814
77	2.00	0.87500	0.84977	0.02523	0.84550	0.02950
78	2.02	0.88636	0.85901	0.02735	0.85678	0.02958
79	2.02	0.89773	0.85901	0.03871	0.85678	0.04094
80	2.07	0.90909	0.88400	0.02509	0.88723	0.02186
81	2.13	0.92045	0.91148	0.00897	0.92022	0.00023
82	2.15	0.93182	0.91741	0.01441	0.92719	0.00462
83	2.17	0.94318	0.92299	0.02019	0.93369	0.00949
84	2.22	0.95455	0.93781	0.01674	0.95051	0.00403
85	2.27	0.96591	0.95005	0.01586	0.96374	0.00217
86	2.52	0.97727	0.98442	0.00715	0.99423	0.01695
87	2.83	0.98864	0.99686	0.00822	0.99972	0.01108
88	2.85	1.00000	0.99712	0.00288	0.99977	0.00023
				Lognormal Maximum Deviation **0.0668**		Normal Maximum Deviation **0.1002**
			D(95%) for N =88	Allowable Maximum Deviation **0.1450**		

Best Fit : **LOGNORMAL**

REPOSITION CYCLE

KS TEST BORROW

Contract #: 4779 County: Obion 11/24/98

Mean	Stand. Dev.	# samples	ζ	λ
0.45	**0.10**	**65.00**	**0.2175**	**-0.8182**

Order	Time	Nondelay Cumulative Frequency	Lognormal Cumulative Probability	Deviation	Normal Cumulative Probability	Deviation
1	0.07	0.01538	0.00000	0.01538	0.00005	0.01533
2	0.27	0.03077	0.01030	0.02047	0.03132	0.00055
3	0.30	0.04615	0.03805	0.00810	0.06344	0.01729
4	0.30	0.06154	0.03805	0.02349	0.06344	0.00190
5	0.32	0.07692	0.06361	0.01331	0.08709	0.01017
6	0.33	0.09231	0.09864	0.00633	0.11677	0.02446
7	0.33	0.10769	0.09864	0.00905	0.11677	0.00908
8	0.33	0.12308	0.09864	0.02444	0.11677	0.00631
9	0.33	0.13846	0.09864	0.03982	0.11677	0.02169
10	0.33	0.15385	0.09864	0.05521	0.11677	0.03708
11	0.35	0.16923	0.14343	0.02580	0.15299	0.01624
12	0.35	0.18462	0.14343	0.04118	0.15299	0.03162
13	0.37	0.20000	0.19735	0.00265	0.19598	0.00402
14	0.37	0.21538	0.19735	0.01804	0.19598	0.01941
15	0.38	0.23077	0.25890	0.02813	0.24558	0.01481
16	0.38	0.24615	0.25890	0.01274	0.24558	0.00058
17	0.38	0.26154	0.25890	0.00264	0.24558	0.01596
18	0.38	0.27692	0.25890	0.01803	0.24558	0.03135
19	0.38	0.29231	0.25890	0.03341	0.24558	0.04673
20	0.40	0.30769	0.32597	0.01827	0.30123	0.00646
21	0.40	0.32308	0.32597	0.00289	0.30123	0.02185
22	0.40	0.33846	0.32597	0.01250	0.30123	0.03723
23	0.42	0.35385	0.39612	0.04228	0.36195	0.00810
24	0.42	0.36923	0.39612	0.02689	0.36195	0.00728
25	0.42	0.38462	0.39612	0.01151	0.36195	0.02267
26	0.42	0.40000	0.39612	0.00388	0.36195	0.03805
27	0.43	0.41538	0.46690	0.05151	0.42636	0.01097
28	0.43	0.43077	0.46690	0.03613	0.42636	0.00441
29	0.43	0.44615	0.46690	0.02074	0.42636	0.01980
30	0.43	0.46154	0.46690	0.00536	0.42636	0.03518
31	0.47	0.47692	0.60166	0.12474	0.55944	0.08252
32	0.47	0.49231	0.60166	0.10936	0.55944	0.06713
33	0.48	0.50769	0.66239	0.15470	0.62444	0.11675
34	0.48	0.52308	0.66239	0.13931	0.62444	0.10136

35	0.48	0.53846	0.66239	0.12393	0.62444	0.08598
36	0.50	0.55385	0.71731	0.16346	0.68608	0.13223
37	0.50	0.56923	0.71731	0.14808	0.68608	0.11685
38	0.50	0.58462	0.71731	0.13269	0.68608	0.10146
39	0.50	0.60000	0.71731	0.11731	0.68608	0.08608
40	0.52	0.61538	0.76596	0.15058	0.74292	0.12754
41	0.52	0.63077	0.76596	0.13519	0.74292	0.11215
42	0.52	0.64615	0.76596	0.11981	0.74292	0.09677
43	0.52	0.66154	0.76596	0.10443	0.74292	0.08138
44	0.52	0.67692	0.76596	0.08904	0.74292	0.06600
45	0.52	0.69231	0.76596	0.07366	0.74292	0.05061
46	0.52	0.70769	0.76596	0.05827	0.74292	0.03523
47	0.52	0.72308	0.76596	0.04289	0.74292	0.01984
48	0.53	0.73846	0.80828	0.06982	0.79389	0.05542
49	0.53	0.75385	0.80828	0.05444	0.79389	0.04004
50	0.53	0.76923	0.80828	0.03905	0.79389	0.02466
51	0.53	0.78462	0.80828	0.02367	0.79389	0.00927
52	0.53	0.80000	0.80828	0.00828	0.79389	0.00611
53	0.53	0.81538	0.80828	0.00710	0.79389	0.02150
54	0.55	0.83077	0.84449	0.01372	0.83832	0.00755
55	0.55	0.84615	0.84449	0.00167	0.83832	0.00783
56	0.55	0.86154	0.84449	0.01705	0.83832	0.02322
57	0.55	0.87692	0.84449	0.03244	0.83832	0.03860
58	0.57	0.89231	0.87499	0.01731	0.87599	0.01631
59	0.57	0.90769	0.87499	0.03270	0.87599	0.03170
60	0.57	0.92308	0.87499	0.04808	0.87599	0.04708
61	0.57	0.93846	0.87499	0.06347	0.87599	0.06247
62	0.57	0.95385	0.87499	0.07885	0.87599	0.07785
63	0.58	0.96923	0.90036	0.06887	0.90705	0.06218
64	0.58	0.98462	0.90036	0.08426	0.90705	0.07757
65	0.58	1.00000	0.90036	0.09964	0.90705	0.09295

Lognormal Maximum Deviation **0.1635**

Normal Maximum Deviation **0.1322**

Allowable Maximum Deviation

D(95%) for N =88 **0.1687**

Best Fit : **NORMAL**

Vita

Richard Gatlin was born in Dyersburg, Tennessee on July 14, 1974. He graduated from Dyersburg High School in 1992, and began his undergraduate studies at The University of Tennessee at Martin. After attending UTM for two years, he transferred to The University of Tennessee at Knoxville. In May of 1997, he graduated with a Bachelor of Science in Civil Engineering. June 1997, he began his graduate studies, and received his Master of Science degree in Civil Engineering in December, 1998.