MODELING DELAY OF LOADING GOODS ON RIVER TRANSPORT VESSELS

Ivan Đorđević [a*], Gordan Stojić [a], Ilija Tanackov [a], Siniša Sremac [a]

[a] University of Novi Sad, Faculty of Technical Sciences, Serbia, ivan.djordjevic87@gmail.com

Abstract: *Transport and handling operations performed in cargo transport terminals can significantly influence speed and efficiency of loading. Loading of goods has its own spatial and temporal dimension. Managing temporal dimension contributes to a more efficient realization of the loading operation and affects the performance of transport and rational handling operations in freight transport terminals. The analysis of parameters which influence the time of loading may contribute to efficient solution of practical problems that slow down loading of goods. In this paper, a simulation model of the process of delay in loading bulk cargo is developed. The model was tested on the roasted iron pyrite in the marine terminal port Sabac. The test results have shown that delay is a significant factor which influence loading of goods. Measuring of delay duration for each loaded vessel was carried out in real conditions of loading and handling operations. As the output of this method, the arrangement of regular duration of delays and disorders is observed. Further analysis shows link between regular duration and disorders and opportunity to predict and control disorders during loading of cargo.*

Keywords: *loading, delay, orderly, disorder, model*

1. INTRODUCTION

Transport of goods by inland waterways is the most capacious and most cost-effective mode of transport. Besides, environmental pollution is incomparably lower, which is very important fact in the planning of sustainable transport network as seen from the view of today's climate disturbances. Pan-European transport corridor VII is a natural, highly capacious waterway that allows the formation of large river transport structures for the transport of mass and containerized cargo [6]. Rational managing and planning of reloading operations in port terminals are an important segment in business of port terminals. Possibility of predicting duration of loading operations is certainly an important organizational and pricing dimension. The objective of the paper is to model and predict delays and their duration on loading of bulk cargo onto vessels.

* ivan.djordjevic87@gmail.com

2. SIMULATION MODEL

2.1 Description of the model

The model encompasses a river terminal for bulk cargo where times of loading and delays were measured out for river vessels. At the river terminal loading place there is a conveyor of 400 t/h capacity with three to five trucks for serving it. Loading times were measured continuously during one year and 250 open type river vessels were included. Measuring was performed for one type of goods, which is massive bulk cargo - roasted iron pyrites [7].

On the duration of times of loading and delays unfavourable weather conditions, such as precipitation, moisture of goods, high water level, availability of trucks serving the conveyor, etc. have significant impact. Delays also included technical operation for loading cargo. The delays were recorded from the moment the loading was interrupted till the loading of the same vessel was continued. Where loading was stopped more than once, the delay was calculated as the sum of all breaks.

In the analytical part of the research, the statistical parameters and border of disorders in delays were established, respectively [3]. The delays that are measured out on loading have extremely high values as a consequence of disorder due to unfavourable impacts.

The occurrence of these values cannot be controlled because of unforeseeable circumstances. For this reason disorders were analyzed as a particular delay category. Namely, the delays are divided in two categories: regular duration and disorder.

On the basis of hypothesis of exponential distribution for the two categories of delay due to their own randomness, the simulation was carried out for both regular duration of delay and disorder. The simulation part implies implementation of Monte Carlo numerical method and use of software to simulate great number of iterations [4]. Further analysis will show linear dependency between regular duration of delay and disorder, as well as the possibility of predicting disorders.

2.2 Delays from the aspect of disorder size

The delay in loading of bulk cargo at the freight terminal was measured out in real conditions for each loaded vessel. Measuring included all influential factors and they are included in final duration of delay. The results of measuring, where delay is a continual random variable *(X)*, have continual distribution and may take random value. Statistical data processing was performed and it showed wide range of the measured values [3]. The Figure 1. shows the histogram containing the measured delays compared with normal distribution.

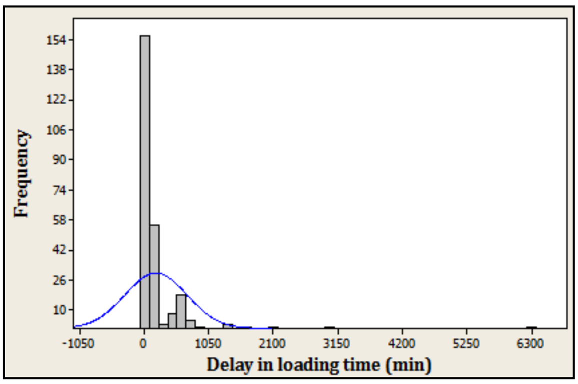

Figure 1. Histogram with measured out delays

In the Table 1. the output results of the statistical delay processing are given.

Since the frequency of the duration of delays measured for all vessels is concentrated on lower values (statistical analysis given in the Table 1. shows that the median is $\tilde{x}$ = 50 min, and the maximum value of the measured delays is *max* = 6360 min), the Figure 2. is obviously really small percent of extreme high duration of delays. These have led research on the conclusion that there are disorders in the duration outages.

In determining classes where border of disorder will be defined, the optimal relation between squared mathematical expectation, $E(x)^2$ and variance, σ^2 was searched. As the disorder classes, the values of delay above 350 min, 450 min, 550 min, 600 min were taken into consideration.

Table 1. Descriptive statistic of delay

Statistical parameters		Obtained values
Number of samples (n)		250
Central tendency	Mathematical expectation, *E(x)*	182,8
	Median, $\tilde{x}$	50
	Standard error, *ε*	32,6
Dispersion of values	Srandard deviation, *σ*	510,2
	Maximal value, *max*	6360
	Minimal value, *min*	0
Shape of distribution	Skewness	8,44
	Kurtosis	92,16

In determining of disorder borders in delays the following relation is taken as optimal:

$$E(x)^2 / \sigma^2 = 0{,}82 \qquad (1)$$

and delays in time with duration over 450 min are declared as disorders. Duration of delays below 450 min is regular duration.

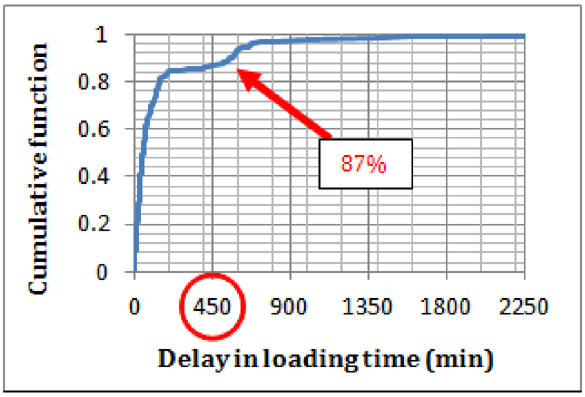

Figure 2. Cumulative function of measured out delays

Observing the cumulative function at the Figure 2. it can be concluded that 87% of all delays have duration below border of 450 min. On this way it is defined participation of all disorders in delays with 13%. Disorders above 650 min are taking only 5% in total number of measuring.

In order to assess matching with mathematical distribution, goodness of fit test is performed. The Anderson – Darling test (*p>0.05*) is carried out using probability plots with 95% confidence interval [1]. The Table 2. shows Anderson – Darling (AD) statistic and the associated power of test (p - value).

Table 2. Anderson – Darling (AD) statistic for mathematical distributions

Specify of mathematical distribution	AD statistic	p - value
Normal	49,581	<0,005
3-Parameter Lognormal	3,295	no data
2-Parameter Exponential	51,761	< 0,010
3-Parameter Weilbull	8,144	< 0,005
Smallest Extreme Value	73,494	< 0,010
Largest Extreme Value	31,722	< 0,010
3 – Parameter Gamma	12,969	no data
Logistic	33,022	< 0,005
3 – Parameter Loglogistic	5,524	no data

From the Table 2. it is obvious that loading delays have feature of random variables and there is no matching with any mathematical distribution (AD statistic is larger than 0 and p – value is not > 0.05).

2.3 Implementation of Monte Carlo method

As the statistical verification confirmed that delays does not match any mathematical distribution, it is assumed that the first category of delay (regular duration) match exponential distribution, while disorders match Erlang distribution. Both category of delay will be presented by probability density function (pdf) of related assumed distribution and will be simulated.

To perform simulation parameter of probability, the density function is determined [5]:

$$\lambda = {}^{1}/_{E(x)} = 0{,}02 \qquad (2)$$

as a border parameter between regular duration and disorder. Regular duration of delay in simulation contains value of the parameter $\lambda>0{,}02$, while disorder contains value of density function parameter, $\lambda<0{,}02$.

On the basis of the measured values of delay for vessels, the calculated mathematical expectation of regular duration is $E(x)=62{,}94$ min, and of disorders, $E(x)=991{,}88$ min. Standard deviation for regular duration is $\sigma=75{,}57$; and for disorders, $\sigma=1093{,}91$. Mathematical expectation is the crucial parameter for further evaluation of efficiency of simulation.

Monte Carlo simulation is performed for $n=10^4$ iterations of randomly chosen values, $x=[0{,}1]$ of function argument [2].

In simulation of regular duration of delay, it was used probability density function of exponential distribution, while disorders were simulated by probability density function of Erlang distribution of the second order.

After $n=10^4$ iterations the simulated mathematical expectation of regular duration takes values that are extremely close to mathematical expectation of the measured values (approximate relative error is 0.003%). Statistical goodness of fit test shows power of test ($p = 0{,}75$) more than 0,05 according to condition $p>0{,}05$ to accept assumed hypothesis. Probability density function of regular duration shows exponential distribution (Figure 3.).

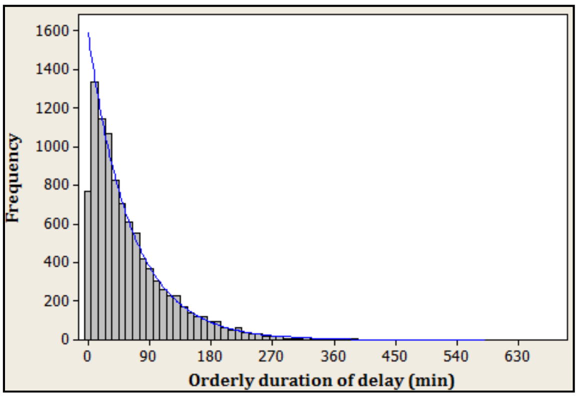

Figure 3. Histogram of probability density function for regular duration

The category of disorder was simulated according to the probability density function of Erlang distribution of the second order. Also, it shows insignificant discrepancy of the simulated mathematical expectation in regards to the mathematical expectation of the measured values (approximate relative error is 0.017%). Statistical goodness of fit test shows power of test (p = *0,250*) more than 0,05 according to condition $p>0,05$ to accept assumed hypothesis and the assumed distribution is valid (Figure 4.).

3. MODEL FOR PREDICTING DISORDERS

After simulation of probability density distribution for both categories of delay, the question is whether the disorders can be managed? How to assess potential duration of disorders?

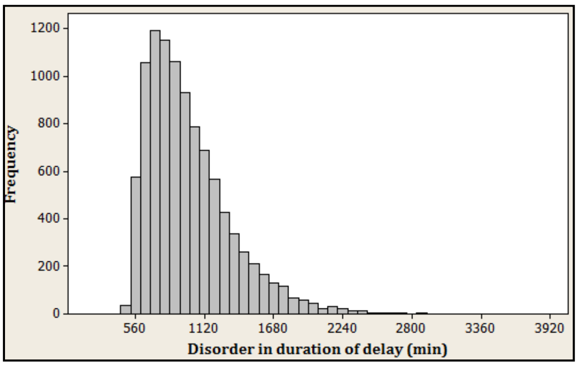

Figure 4. Histogram of probability density function for disorders

The answers to these questions are given through the analysis of disorders in percentage in regards to regular duration of delay. Disorders were analyzed in ranges of 5% beginning from the mathematical expectation of regular duration (E(x) = 63 min, disorder is 0%) till the mathematical expectation of disorders (E(X) = 992 min, disorder is 100%). The average mathematical expectation (AME) in the Table 3. was estimated from 10 measurements of simulated mathematical expectations for regular duration and disorders, and represents total duration of delay.

Table 3. Calculated AME in regards to size of disorders in percentage

Percentage (%)	0	5	10	15	20	25	30	35	40	45	50
AME (min)	63	109	155	201	248	294	340	386	432	478	525
Percentage (%)	55	60	65	70	75	80	85	90	95	100	
AME (min)	571	617	663	709	755	801	848	894	940	992	

On the basis of the measured AME given in the Table 3. the mathematical model for duration of delay is developed:

$$T_d = (T_{disord} - T_{order}) * p + T_{order} \quad (3)$$

Where:

T_d – is the duration of delay;

T_{disord} – is the duration of disorders (AME = 992 min);

T_{order} – is the regular duration (AME =63 min);

p – is the percentage of disorders.

4. CONCLUSION

Every reduction of delay in loading time has direct influence on reduction in total loading time per transport unit and more efficient utilization of conveyor and staff. Modelling of disorders and their prediction is important element of rational business in freight transport terminals.

In second part of the research, the model for prediction of disorders was developed. The linear regression model with extraordinary correlation was obtained. Control of unpredictable duration of potential disorders is an important factor in efficient organizing of reloading operations in freight terminals.

The proposal for further research is to analyze the delay impact on total loading duration. It is necessary to take into consideration the possibility to predict loading delay, as well as to prognoze loading duration on the basis of potential delays. Also, further analysis of impact should include the trucks available to serve at river terminal, the time of truck turnaround, number of working machines and technology of goods preparation for loading. On the basis of these analyses the model for delay predicting could be upgraded.

ACKNOWLEDGMENT

The authors acknowledge the support of research project TR 36030, funded by the Ministry of Science and Technological Development of Serbia.

REFERENCES

[1] Bass I., (2007). Six Sigma Statistics with Excel and Minitab, The McGraw-Hill Companies, Inc., USA.

[2] Fishman, S. G., (1999). Monte Carlo Concepts, Algorithms and Applications, Springer Series in Operations Research, Springer.

[3] Fraser, D. A. S., (1958). Statistics – An Introduction. John Wiley & Sons, Inc., New York, USA.

[4] Mun, J., (2006). Modeling Risk: Applying Monte Carlo Simulation, Real Options Analysis, Forecasting, and Optimization Techniques, Wiley.

[5] Đorić, D., et al. (2007). Atlas raspodela, Matematički fakultet, Beograd.

[6] www.dunavskastrategija.rs

[7] www.elixirzorka.rs