THE FUNCTION FOR PREDICTING OF THE TRUCK MIXER MOVEMENT SPEED

Biljana Matejević [1]
Jelena Jovanović [2]

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Summary: *The paper presents functions for determining the movement speed of the truck mixers when transporting concrete to the site. Functions based on the collected data during the concreting of columns, walls, slabs and beams at the construction sites in Nis have been formed. Since the supply of some of the observed construction sites was from concrete factories located in the city itself, and some were supplied from factories outside the city, two functions were proposed for calculating the speed of the mixer movement. These functions for predicting the movement speed, and thus determining the time required for the arrival / departure of the mixers to / from the site, can be useful in calculating the duration of the truck mixer cycle, performance, as well as determining the number of truck mixer needed for synchronized operation with the unloading machine.*

Keywords: *Function, truck mixer, movement, speed, duration, concrete*

1. INTRODUCTION

Concrete works are certainly one of the most important groups of works in the construction of almost any type of buildings in the building construction. According to the regulations, the use of ready-mixed concrete made in the concrete plant for the construction of supporting structures is required. For the transport of fresh concrete mass made in the concrete plant to the construction site, the use of a truck mixer is the most widespread. The mixer cycle starts with the loading of fresh concrete in the concrete plant, continues to transport to the construction site, where the unloading takes place and ends with return to the concrete plant in order to load a new amount of concrete. The duration of the individual parts of the cycle is variable and depends on the numerous and variable influencing factors.

In order to achieve higher productivity of performance of concrete work, it is necessary pay attention to good synchronization of machinery and reduce unnecessary delays and waste of time. Because of that, it is important to more precisely calculate (predict) the duration of individual operations and processes.

[1] Biljana Matejević, PhD., University of Niš, Faculty of Civil Engineering and Architecture Niš, Aleksandra Medvedeva, 14, Niš, Serbia, tel: +381 18 588 202, e – mail: biljana.matejevic@gaf.ni.ac.rs
[2] Jelena Jovanović, M.Eng., University of Niš, Faculty of Civil Engineering and Architecture Niš, Aleksandra Medvedeva, 14, Niš, Serbia, tel: +381 18 588 202, e – mail: jelena.stojiljkovic@gaf.ni.ac.rs

The paper proposes functions for determining the speed of movement of truck mixer when transporting concrete to the construction site, as part of the cycle of its work. Based on the collected data during the concreting of columns, walls, slabs and beams at the construction sites in Nis, functions were formed. Since the supply of some of the observed construction sites was from concrete plants located in the city itself, and some were supplied from concrete plants outside the city, two functions were proposed for calculating the speed of the truck mixer movement.

2. TRUCK MIXER

Truck mixer is a transportation means for the transportation of fresh concrete from the concrete plant to the construction site. Calculation of the practical performance of truck mixers, as machines with cyclic way of work, is of great importance for determining more realistic duration of work on the site, and hence the greater accuracy of the work plans. It is especially important that it is more accurate to calculate the duration of the work cycle, as an important data in the procedure for calculating the practical performance.

In the literature, the most frequent way to calculation of the transport vehicle operation cycle duration, so and the truck mixer, is calculated as the sum of the time needed for loading, travelling of full truck mixer, unloading and returning an empty vehicle [4]:

$$t_c = t_u + t_o + t_i + t_p \qquad [\mathrm{min}] \tag{1}$$

where:

t_u – time required to loading truck mixer (min)
t_o – time required to travelling of full truck mixer (min)
t_i – time required to unloading truck mixer (min)
t_p – time required to returning an empty truck mixer (min)

The departure time and the return of the mixer depends on the transportation distance and the average speed of movement [4]:

$$t_o = \frac{L}{V_o}; \qquad t_p = \frac{L}{V_p} \qquad [\mathrm{min}] \tag{2}$$

where:

L – transportation distance (km)
V_o, V_p – speed of departure/return od truck mixer (km/h)

As the transport distance is measurable and known size, in order to determine the exact duration of the concrete transport, it is necessary to predict the average speed of the vehicle. Speed of movement is variable size and depends on a large number of factors, such as:

- the movement of the truck mixer (driving through the city or the out of the sity)
- vehicle condition (age, reliability, maintenance, size, type, ...)

- condition of the road (type of roadway, road condition, ...)
- time interval (time of day, week, year, ...)
- driver's competence (experience, training, motivation, ...)
- weather conditions (summer, winter, precipitation, ...), etc.

In accordance with our regulations, the transport of concrete by truck mixer, must not be longer than 30 min, in order to preserve its designed quality [3].

Figure 1. Transport of concrete by truck mixer throught the city

In order to more accurately calculate the duration of the work cycle, and therefore the practical performance of the truck mixer, the idea was that instead of assuming the average speed of movement, a function would be determined to better represent of the truck mixer movement average speed. A part of the database collected for the purpose of studying the productivity of the concreting process [2] was used to determine the function. Data on the duration of the transport of concrete from the concrete plant to the construction site, were obtained through a multi-month long recording of the concreting process at the construction sites in Niš.

3. THE FUNCTION FOR PREDICTING OF THE TRUCK MIXER MOVEMENT SPEED

Monitoring the process of concreting consisted of recording the time needed in specially prepared forms. The time of the truck mixer arrival on the construction site was recorded, and the delivery time from the concrete plant was taken from the delivery note (Figure 2). Based on this, the duration of the concrete transport was calculated.
The collected data were divided into two groups depending on the route that the truck mixers were moving: transport through the city and transportation outside the city. It has

been noted that different average speeds are achieved for these two ways; less speeds were realized, of course in the first case, due to traffic lights, intersections, city crowds, etc.
Based on the distance of the corresponding concrete plant from the observed construction site and the achieved transport time, the speed of the truck mixer movement was calculated, sorted in relation to the transport route, and the corresponding theoretical probability distribution functions were obtained.


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Vrsta betona MB	Izdata količina (M3)	Maksimalno zrno	Mera sleganja cm	Dolazak na objekat	Početak istovara	Kraj istovara	Vozilo	Doza ža br.
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Cement:
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Napomena: - od momenta spravljanja beton mora biti ugrađen najviše za 90 minuta.
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Vozač u načelu nema pravo da betonu dodaje dodatnu vodu. Sve naknadne promene betona oslobađaju nas garancije.
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Naknadni dodatak
Mesto dodavanja:
Vreme dodavanja:
Dodata količina: litara / vozilo
Oznaka:
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Dodatak tečnog sredstva / naknadno doziranje
max. Dodata količina:
Dodata količina: litara /
Vreme dodavanja:
Konzistentnost pre/posle dodavanja tečnog sredstva:

Figure 2. The delivery note for concrete transport by truck mixer

After statistical processing, for the transport of concrete to the construction site in case of driving through the city, it wasobtained that is the best to present the speed of movement by the Beta4 distribution function [1]:

$$g(x) = \frac{1}{B(a,b)} \frac{(x-c)^{a-1}(d-x)^{b-1}}{(d-c)^{a+b-1}}, \quad c \leq x \leq d \tag{3}$$

where:
a,b (a>0, b>0) – shape parameters,
c, d (c, d∈R, c<d) – the smallest and greatest value of the random variable.

In the case of driving outside of the city, it was obtained that it is the best to present the speed of movement, also with the Beta4 distribution function, with different parameter values.

The Beta4 function serves to describe various events that are characterized by random quantities whose values are in the final interval [1].

Table 1. Theoretical distribution of probability for the achieved speed of transport through the city

Distribution	p-value
Beta4	**0.834**
Chi-square	< 0.0001
Erlang	< 0.0001
Exponential	< 0.0001
Fisher-Tippett (1)	< 0.0001
Fisher-Tippett (2)	0.062
Gamma (1)	0.012
Gamma (2)	0.696
GEV	0.823
Gumbel	< 0.0001
Log-normal	0.723
Logistic	0.630
Normal	0.738
Normal (Standard)	< 0.0001
Student	< 0.0001
Weibull (1)	< 0.0001
Weibull (2)	0.715
Weibull (3)	0.782

Table 2. Testing of the superposition between the empirical and theoretical Beta4 distribution of probabiliy

Kolmogorov-Smirnov test:	
D	0.074
p-value	0.834
alpha	0.05

Table 3. Parameters of Beta4 distributionof probability

Parameter	Value	Standard error
a	1.546	0.247
b	1.574	0.252
c	14.828	0.314
d	24.101	0.000

The zero hypothesis was tested: the empirical distribution considered has the characteristics of the Beta4 distribution and the alternative hypothesis: the considered empirical distribution has no Beta4 characteristic. Based on the Kolmogorov-Smirnov test (Table 2), as p-value is 0.834 far greater than $\alpha = 0.05$ (Table 1), the zero hypothesis is accepted at a confidence level of 95% [5]. The risk of rejecting the zero hypothesis if it is true is 83.36%. Table 3 gives the parameters of the Beta4 distribution for the achieved speed of movement.

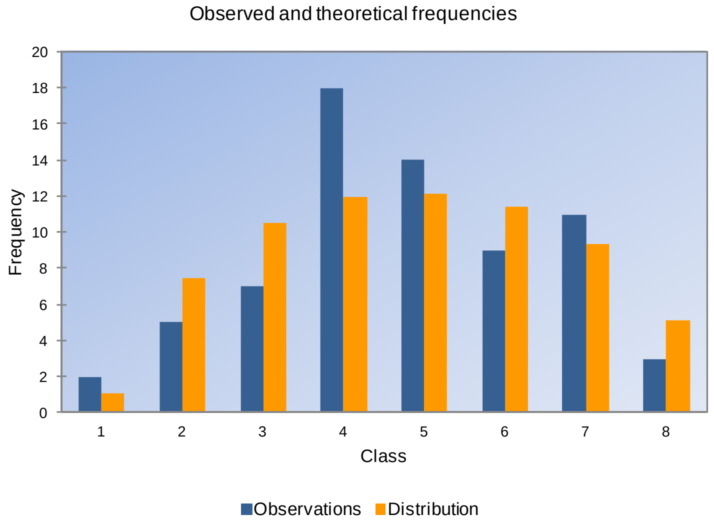

Figure 3. Frequencies of the achieved speed of movement through the city and theoretical values of Beta4 distribution probability

Figure 3 shows the frequency of the achieved speed when moving the truck mixer in city driving and the theoretical values based on the considered function.

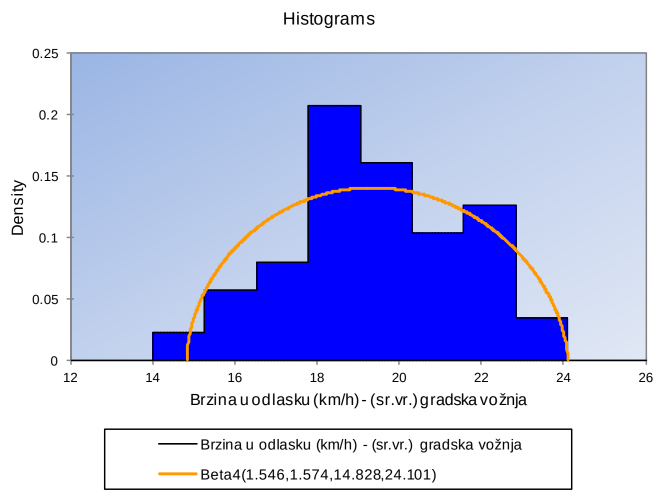

Figure 4. Histogram of distribution of probability the speed movement realized through the city and the theoretical values of the Beta4 distribution

Figure 4 presents the histogram of the probability of the achieved speed and the curve of the Beta4 function in the case of city driving, while Figure 5 shows a cumulative view for the same probability. It can be noted that a good agreement of the empirical distribution with theoretical is achieved, as confirmed by previous tests.

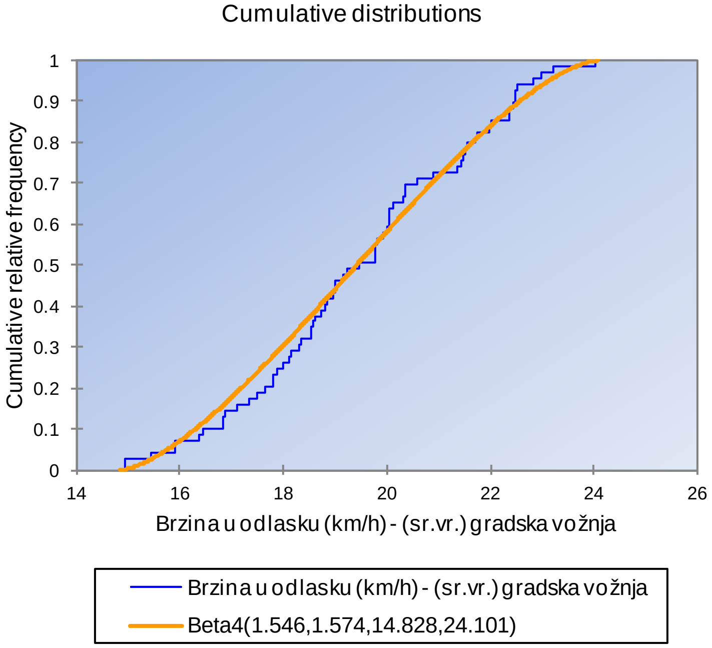

Figure 5. Cumulative presentation of the superposition of empirical and theoretical values of the realized movement speed through the city

In the case of driving outside of the city, the movement speed is the best to present, also with the Beta4 distribution function, with different parameter values (Table 6).

Table 4. Theoretical distribution of probability for the achieved speed of transport outside of the city

Distribution	p-value
Beta4	**0.887**
Chi-square	0.240
Erlang	< 0.0001
Exponential	< 0.0001
Fisher-Tippett (1)	< 0.0001
Fisher-Tippett (2)	0.096
Gamma (1)	0.033
Gamma (2)	0.389
GEV	0.612
Gumbel	< 0.0001
Log-normal	0.395
Logistic	0.538
Normal	0.548
Normal (Standard)	< 0.0001
Student	< 0.0001
Weibull (1)	< 0.0001
Weibull (2)	0.644
Weibull (3)	0.465

Table 5. Testing of the superposition between the empirical and theoretical Beta4 distribution of probability

Kolmogorov-Smirnov test:	
D	0.100
p-value	0.887
alpha	0.05

Table 6. Parameters of Beta4 distribution of probability

Parameter	Value	Standard error
a	0.934	0.216
b	0.916	0.211
c	20.960	1.516
d	54.327	0.000

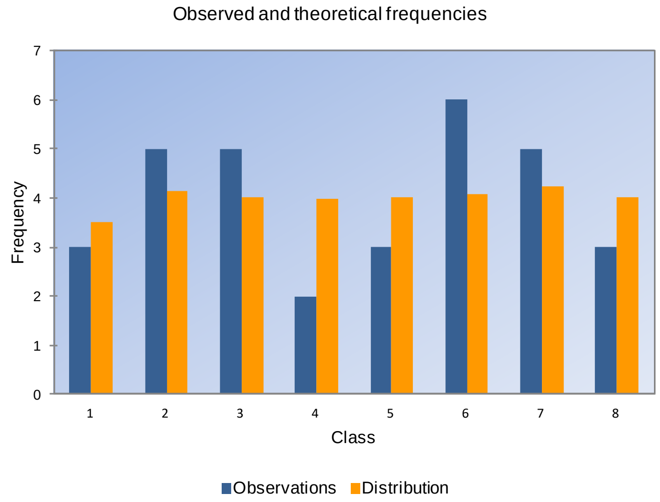

Figure 6. Frequencies of the achieved speed of movement outside of the city and theoretical values of Beta4 distribution probability

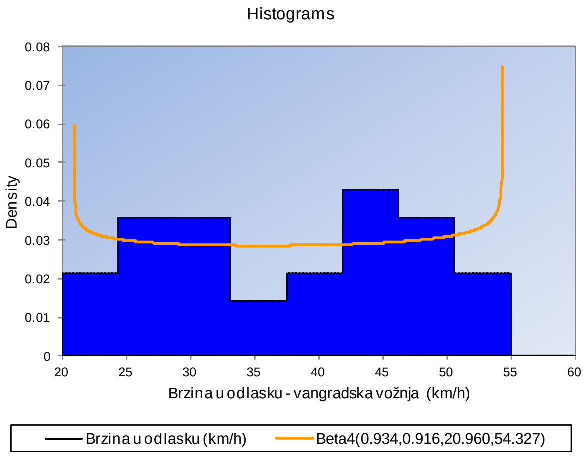

Figure 7. Histogram of distribution of probability the speed movement realized out of the city and the theoretical values of the Beta4 distribution

Figure 6 shows the frequencies of the achieved speed when the truck mixers moving out of the city and the theoretical value based on the considered function .
Figure 7 presents the histogram of the probability of the achieved speed and the curve of the Beta4 function in the case of out of the city drive, while Figure 8 shows a cumulative view for the same probability. It can be noted that in this case satisfactory agreement of the empirical distribution with theoretical was achieved, as confirmed by the tests carried out.

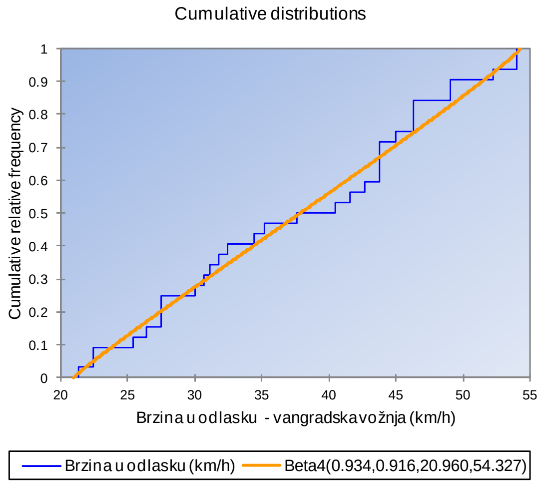

Figure 8. Cumulative presentation of the superposition of empirical and theoretical values of the realized movement speed out of the city

4. CONCLUSION

As the calculation of the duration of the truck mixer cycle takes the assumed speeds in the expression to calculate the time needed for the transport of concrete to the construction site, which can be very different from the ones achieved, the functions are proposed, which can be useful for the purpose of more accurate calculations. Consequently, the exact duration of the cycle has an impact on a better forecast of practical performance, as well as for determining precisely the number of vehicles needed for synchronized operation with the unloading machine. All this contributes to a better planning of the execution of works, as well as achievement the specified deadlines for the completion of projects.

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ФУНКЦИЈА ЗА ПРОЦЕНУ БРЗИНЕ КРЕТАЊА АУТОБЕТОНСКЕ МЕШАЛИЦЕ

Резиме: *У раду су предложене функције за одређивање брзине кретања миксера при превозу бетона до градилишта. Формиране су функције на основу прикупљених података приликом бетонирања стубова, зидова, плоча и греда, на градилиштима у Нишу. Пошто је снабдевање неких од посматраних градилишта било из фабрика бетона које се налазе у самом граду, а нека су се снабдевала из фабрика ван града, то су и предложене две функције за израчунавање брзине кретања миксера. Ове функције за процену брзине кретања, а самим тим и одређивање времена потребног за долазак/одлазак миксера на/са градлишта, могу имати корисну примену при израчунавању трајања циклуса рада, практичног учинка, као и за одређивање потребног броја возила за синхронизован рад са истоварним машином.*

Кључне речи: *Функција, миксер, кретање, брзина, време, бетон*