EXPLOTACIÓN Y PROCESOS MECANIZADOS
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ARTÍCULO ORIGINAL

Use of Queueing Theory to organization of the complex rice harvest-transport on the Agroindustrial Rice Complex "Los Palacios"

Uso de la Teoría de Colas para la organización del complejo cosecha-transporte del arroz en el Complejo Agroindustrial Arrocero "Los Palacios"

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ABSTRACT. The present research was carried out on the Agroindustrial Rice Complex "Los Palacios", on Pinar del Rio province. The investigation had as main goal the study of the means stop probabilities, on the base of stochastic process, considering economical features that appear during the work of the complex rice harvest-transport with the harvester machine New Holland TC-57 and the joint tractor New Holland TS-6020 with trailers RA-6, looking for its rational organization. For the solution of this problem was used the Queueing Theory, taking the economical criteria of itsoptimization the minimum added expenses in one hour by harvester machines and means of transport stops in service, besides it is determined the quantity means of transport for a harvester brigade under probabilistic basis.

***Keywords*:** rice, probabilities, mechanization.

RESUMEN. La presente investigación se realizó en el Complejo Agroindustrial Arrocero "Los Palacios", provincia Pinar del Rio. La investigación tuvo como objetivo principal el estudio de las probabilidades promedio de paradas, sobre la base de los procesos estocásticos, considerándose el aspecto económico durante el trabajo del complejo cosecha-transporte del arroz con la cosechadora New Holland TC -57 y el conjunto tractor New Holland TS-6020 con remolques RA-6, buscándose de esta forma su organización racional.Para la solución de este problema se utilizó la Teoría de Colas, tomándose el criterio económico de los mínimos gastos sumados por paradas de las cosechadoras y los medios de transporte, ademas se determinó la cantidad de medios de transporte para una brigada de cosecha bajo bases probabilísticas.

Palabras clave: cosecha mecanizada de arroz, teoría de las probabilidades, sistemas mecanizados.

INTRODUCTION

For the organization of the harvest-transport brigade of the rice it is important to consider technical and economical aspects, having in mind the minimum expenses for unit of time and/or unit of grain harvested and transported, where a noticeable influence is made by the harvester machine productivity, the means of transport capacity, the distance of transportation, the vials type and conditions, the waiting time to the charge of grain on the field and the discharge on the Reception Center (Betancourt & Bullaín, 2007).

The Queueing Theory was studied by (A. Kaufmann, 1981) and others authors (Buffa, 1968; Escudero, 1972; Cooper, 1981; Gross and Harris, 1985; Kashyahp & Chandry, 1988; Medhi, 1991; Walfrand, 1988; Wolff, 1989; Martinez, 2004) making possible the analysis of waiting phenomenon that is related with the stochastic process, through mathematical models, that make possible to annex the probabilities; besides facilitating to make decisions that give us the possibility to improve the process organization and the systems rationality on the basis of costs reduction.

There are few developed research about the Queueing Theory use in the agricultural process, for that reason the present research is about the technological harvest-transport process of the rice, making an analysis of every component that conform the complex and there were determined the indicators and parameters that made an influence in the efficiency of this process. Determining the organization of the process harvest-transport means, considering the economical criteria of the minimum added expenses for the harvester machine and the means of transport stops during one hour.

METHODS

Theoretical fundaments to the organization of the rice harvest-transport process

During the mechanized harvest flow several kinds of machines are used, such as: harvester machines, means of transport and Grain Reception Center. The condition of continuity of productive flow is the equality between productivities of every mechanized link for a brigade.

$$n_1 W_1 = n_2 W_2 = ... = n_i W_i \qquad (1)$$

Where:

n_i – Quantity of joints for a link i determined;

W_i –productivity of the joint in the productive link i.

During the harvest-transport process the pendulum route is used (distance travelled with charge until the Reception Center and distance travelled empty till the field) (Iglesias *et al,* 2012; González, 1993).

Determination of the harvest-transport means organization using the Queueing Theory

The effective work of the harvest-transport complex depends on the transport service organization; therefore the rational determination of this means presents some difficulties during the productive process.

In production conditions, in the moment of harvester machine is fulfilled with grain and the arrival to the field of the means of transport don't correspond. For this reason the duration of the turn time, depends on the movement speed, of the times used in the Reception Center, and for the harvester machine location on the field and in the path outside the field. Other causes that have an influence in the harvester machine fulfilling with grain are: the relief, the productive yield, the grain humidity during the working day, etc. All the things previously mentioned can produce the unproductive stop of the harvester machine and means of transport. (Iglesias *et al,* 2011; Iglesias, 2006).

Economically is convenient the minimum relation between the quantity of harvester machine and means of transport (Pérez and Iglesias, 1992). This criteria is achieved by the following expression:

$$S = C_{PC} \cdot \lambda \cdot t_{esp} + C_t \cdot n \longrightarrow \text{min, peso/h} \qquad (2)$$

Where:

C_{PC}- Losses per one hour of harvester machine stop waiting the means of transport to serve, peso;

λ – Mean quantity of harvester machine fulfilled of grain (Demand of service in one hour);

t_w- Waiting mean time of every demand, h;

C_t- Cost per hour in the maintenance of the means of transport, peso/h;

n- Quantity of means of transport to give services to a harvester machines group.

In the queueing system it is used the stationery single flow of Poisson, which is free of consequences. This means that in equal time the demand of a service for two or more is few probable, for this, it is important consider the following hypothesis:

1st- The probability P_c (t) doesn't depend of the time interval and don't have dependence of the initial time;

2nd- Two events don't occur never at the same time (the probability that two events happen together is very small);

3rd- If it is considered a very small time interval λ Δt, selected in whichever instant, the probability is equal to Δt; the quantity λ is called mean rate of enters or demand average of service in a unit of time.

The magnitude φ can be whichever (coefficient of system charge). A steady regime exists when $\varphi < n$, in contrary case $\varphi \geq n$ the system can't satisfy the demand and the queue grow indefinitely.

RESULTS AND DISCUSSION

Determination of the harvest-transport means organization using the Queueing Theory

For the determination of the rational quantity of transport means was taken a harvest-transport brigade conformed by three harvester machines New Holland TC-57 and a transport link conformed by tractors New Holland TS-6020 everyone with two trailers RA-6. The rice field had a mean yield of 3,7 t/ha, and the transportation distance was of 13 km on pavement and 5 km on land from to the harvest field until the Reception Center. The results obtained were the following:

- The productivity of the harvester machine in explotation time to an agricultural yield of 3,7 t/ha was 3,03 t/h.
- The cycle time was of 4,02 h, this value is considered elevated, the main cause of this value was the vials conditions.

Using the expression 4 was possible determining the quantity of means of transport without considering the probabilities being this 4,56 means, but for the real conditions four means were considered, taking this quantity of means as comparison base for two, three, four, five and six means of transport, to determine the probabilistical and economical characters.

The mean time of the harvester machine to fulfill its capacity for this yield was 0,45h, So in one hour the channel (λ) can satisfy 2,22 joints of transport.

TABLE 1. Result of the probabilistically character to organize the harvest-transport brigade

Indicators	Quantity of means of transport				
	2	3	4	5	6
Capacity of the service channel (μ)	0,49	0,74	0,99	1,24	1,49
Coefficient of system charge (φ)	4,53	2,23	2,24	1,79	1,48
Probability that two enters (harvester machines) demand a service at the same time (P_c (t))	0,059	0,059	0,059	0,059	0,059
Probability that all service channels (transport) stop (P_o)	-	0,073	0,097	0,17	0,22
Probability that all enters (harvester machine) are exactly busy (P_C)	-	0,47	0,63	0,82	0,73
Probability that exist a queue in the harvester machine service (P_{queue})	-	0,53	0,37	0,18	0,27

The Table 1 shows the probabilistical character of the harvest-transport; when the quantities of means of transport change, showing that with five means of transport the probability that exist a queue in the harvester machine service is lower.

TABLE 2. Result of the determination of rational variant to organize the harvest-transport brigade

Indicators	Quantity of means of transport				
	2	3	4	5	6
Quantity of means of harvester machine in waiting to be served (m_s).	-	3,93	2,54	2,30	2,25
Waiting mean time in queue of the harvester machines (t_{esp}), h.	-	1,77	1,14	1,03	1,01
Losses per harvester machine stops, peso/h.	-	104,6	67,36	60,86	59,68
Losses per means of transport stops, peso/h.	-	6,36	8,48	10,60	12,72
Addition of losses per stops, peso/h.	-	110,96	75,84	**71,46**	72,4

The Table 2 shows the determination of rational variant to organize the harvest-transport brigade on economical base, showing that with five means of transport the value of the addition of losses per stops is lower.

CONCLUSIONS

- This research validates the aplication of Queueing Theory for the rational organization of the harvest-transport complex, considering probabilistical and economical aspects.
- The probabilistical character is directly proportional to the addition of losses per stops, because of the variant of five transport joint it is obtained the minimum cost per stops and the minimum probability that exist a queue in the harvester machine service.
- The rational quantity of transport joints is five with a cost of 71,46 peso/h, that in comparison with the actual composition with a cost of 75,84 peso/h, it is obtained an income of 43,8 peso per a working turn.

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