OPTIMIZATION OF INTERNAL LOGISTICS IN A WASTE MANAGEMENT COMPANY WITH QUEUING THEORY

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Abstract: *The number of companies for collection, processing and disposal of waste is increasing, as is the amount of waste we produce. Bigger companies have their own vehicle fleet, their own collection centers and they often cover large geographical areas. For such network of supply of services, a quality logistic organization is needed. The paper focuses on a case study of a Slovenian waste management company, which has a well-organized external logistics system on one hand, but a lacking organization of internal logistics on the other. The paper will focus on potential for optimizing the process of vehicle weighing and fuel filling, since this process represents a bottleneck of the internal logistics. Congestions appear often due to excessive vicinity of the weighing device and the gas pump. During the refueling of a bigger truck the weighing device becomes useless as the truck trailer is still standing on the balance. The paper will present different improvement scenarios for internal logistics, which will be calculated using stochastic processes and queuing theory.*

Keywords: *waste management, internal logistics, queuing theory, case study*

1. INTRODUCTION

Logistics functions can be divided into external and internal, and this paper will focus on the latter. Internal or in-house logistics is comprised of transport in a company, all internal processes and all internal flows of materials and people. Many costs can be avoided with optimal planning of these processes. In the past it has been shown that in the short term, many optimization changes are not sensible, but in the long run may mean a significant move in the direction of optimal logistics. This is the case also in the researched company for the collection, treatment and disposal of waste. Because of the bottleneck in the process of weighing trucks on returning to the collection center and refueling with gas, losses are caused by waiting. Hourly rate of the driver, vehicle depreciation, opportunity costs, longer operating costs and much more are costs, which the company is not aware of and so far have not been measured. The focal company has been increasingly faced with spatial problems in recent years due to the increased volume of work, which in turn affects poor organization of internal transport at the collection center. The aim of the research is to examine the processes of internal transport at the collection center of the company and thus show the current situation. Processes will be examined by a thorough analysis of the data, mostly focusing on the bottleneck situations. The final goal is to demonstrate how using queuing theory can affect a company's performance and improve processes which in turn means reduced optimized internal logistics to save on the cost of the organization, labor costs, cost of resources and time.

2. METHODOLOGY

The case company is located in Slovenia and covers a large portion of its vicinity in terms of general waste management services. Additionally, they perform services of specialized waste management for known customers, such as medical or metal waste disposal and recycling.

Research for this paper is performed in three segments. First, it is necessary to analyze the current situation with the use of longitudinal data, topological layout analysis and internal transport processes. With this, the actual losses of time in different situations will be possible to calculate. Based on this, a queuing model will be assembled in order to further assess processes of internal transport. Finally, possible scenarios for improvements will be presented.

The processes of internal logistics in the case company can be described as queues and therefore have the potential to be analyzed and optimized using queuing theory. Queuing systems include one or more servers, queuing nodes - customers requiring service, and the process of serving. Where it is not possible to serve all customers at the same time, customers must wait to be served in a queue (Hudoklin-Božič, 1999, p. 136). In the presented case, the customers of the queue are the drivers of cargo vehicles, which carry the waste and other material into the collection center. Servers are the scale where vehicles are weighed and the fuelling tank. If the number of vehicles weighing in and refueling is more than one, this results in queues. The arrivals of vehicles to the collection center are not at regular intervals, therefore the succession of arrivals of vehicles to the center forms a Poisson process.

According to Hudoklin-Božič (1999, p. 139), the M / M / 1 queuing system is subject to an input stream of customers described as a Poisson process, serving times are exponentially distributed, the number of servers is 1. Such queuing systems ca appear in practice also in a slightly modified or more complicated version – when the queue is in fact a network, consisting of two stations in a tandem with a finite intermediate buffer (see Tsiotras, Badr & Beltrami, 1987).

Applied to the situation in the case company, such a system can be used to determine the operating capacity of the weighing scale and fuel pump as two independent units, which are also co-dependent because of their placement in the topology of the collection center. These are the basic arguments and assumptions that are based on an assessment of internal logistics processes at the collection center of the company. Due to this topography, the queuing system in the company is a two-stage tandem queuing system with two stations and a finite buffer between both stations, where the scale is the first station and the weighing unit is the second station, interdependent on the scales.

3. ANALYSIS OF INTERNAL LOGISTICS IN THE CASE COMPANY

Basic and also the main activity of the company is collecting, processing and disposal of waste. Location of their collection center is less than 5 km off the main highway, which does not cause logistical problems. The biggest logistical problem is represented by internal layout of buildings and lack of maneuverability areas for large vehicles.

In Figure 1, internal flow of transport is shown. Vehicles that enter the collection center are obliged to weigh in, except if they are empty. In this case, they turn left, past the scale. Upon completion of the weighing process, certain vehicles refuel, other continue to the destination in the center. The vehicles which are owned by the company must always refuel only at the collection center and not on any other external fuel stations.

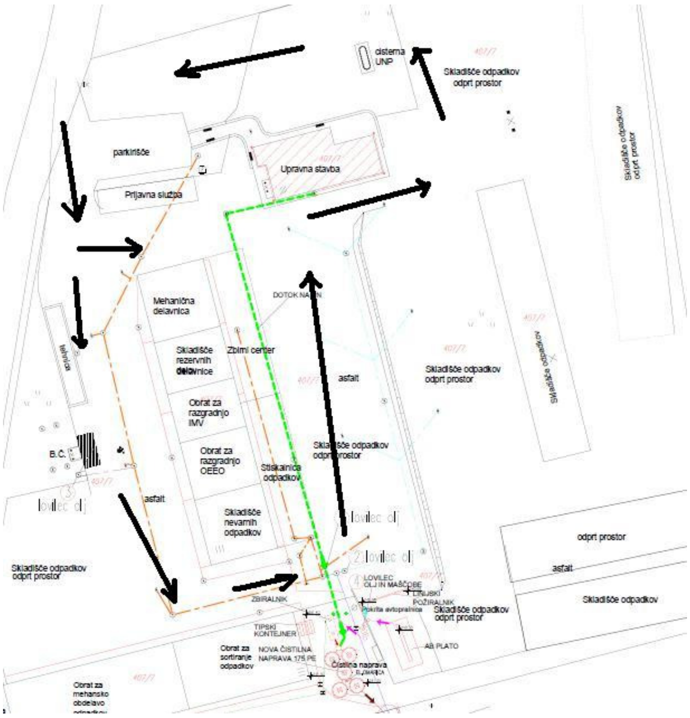

Figure 1. Layout of the collection center and internal transport flows (Source: Internal data from the case company, 2013)

2.1 Refueling and weighing

During the company's daily operations, on average 83 vehicles are weighed, while 13 vehicles averagely refuel. Towards the end of the month, that number rises for as much as 50%. Bottlenecks and losses are generated mostly in the process of weighing and refueling the vehicle. Every vehicle in the center brings waste, must necessarily be weighed first. Because of this, drivers must wait up to 30 minutes to be able to weigh the vehicle and must not complete any other operation prior to that. Weighing vehicles takes on average not more than two minutes, meaning that the average waiting period should not be more than 6 minutes. The flow of vehicles is stopped if any vehicle is refueling. Due to lack of space in the area of the scale and refueling unit, vehicles cannot leave the scale if a vehicle is refueling and cannot even pass by.

The first step was to analyze longitudinal data concerning weighing and refueling. Table 1 shows the recorded data on the number of refuels during the months of January 2013 through October 2013 with a total sample of 272 working days. The average flow of the fuel tank is 70 l / min, with an average of vehicles pumping 155,4 liters of fuel at a time. The analysis of refueling times in relation to the entire sample shows that most refueling occurs in two peaks. Most refuels occur in the morning between 6 and 7 am, when the vehicles are leaving the center, and another peak is in the hours between 14 and 17 pm after the vehicles return. A graphical representation is shown in Figure 2. Additionally, in-depth observations of internal logistics on the company location was performed in the period between 30. September 2013 and 6. October 2013. Analysis of observed data shows that the highest average of arrivals for refueling per hour is 3 vehicles, which is in the period between 14 and 15 pm. Average serving time for refueling was 5,25 minutes.

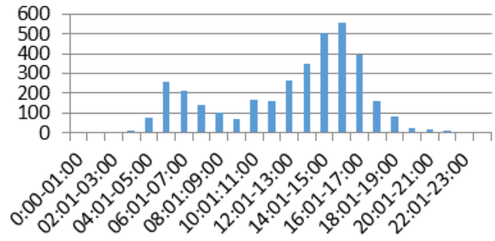

Figure 2. Distribution of refueling occurrences by hours of the day

The same analysis was prepared for the arrival of vehicles to the weighing scale. This distribution by hours of the day is shown in Figure 3. The data shows the entire period of 2013, i.e. 365 days. On the graph of the number of weighings by hours it can be observed that the density distribution is a little different than the distribution of arrival for refueling. Most of the weighings occur between 13 to 14 hours, a little less in the hours before and after this time. The average time for weighing is 2 minutes.

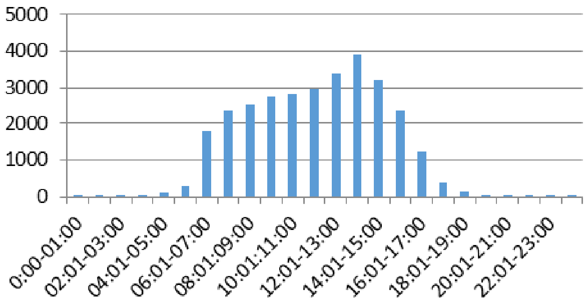

Figure 3. Distribution of weighing occurrences by hours of the day

If the two distributions are compared, it is evident that the greatest potential for congestion in front of the scales is between 13 and 15 pm.

2.1 Queue model

For each server, namely the weighing scale and fuel tank, stochastic processes can be used to analyze and optimize the serving processes. M / M / 1 model of queuing is the basic model with stochastic processes, based on an infinite population of customers and serving discipline "first come, first served". This is the case in the weighing and refueling processes in the case company. The vehicle which first moves onto the scale will be weighed first, and the vehicle which first moves to the fuel pump will be the first to refuel. Since each server is treated separately, it is sufficient to calculate the basic M / M / 1 model.

For the calculation of the queuing model, the following calculations are needed (Cloud & Rainey, 1998, p. 66):

- utilization of servers; $\rho = \frac{\lambda \cdot E(W_S)}{c}$ (1)
- probability that the servers are busy; $C\ (c,\rho) = \frac{\frac{(c\cdot\rho)^c}{c!}\cdot\frac{1}{1-\rho}}{\sum_{n=0}^{c-1}\frac{(c\cdot\rho)^n}{n!}+\frac{(c\cdot\rho)^c}{c!}\cdot\frac{1}{1-\rho}}$ (2)
- average number of waiting vehicles $L_q = E\left(N_q\right) = \frac{\rho\cdot C(c,\rho)}{1-\rho}$ (3)
- average waiting time in the queue $E\left(W_q\right) = \frac{E(W_S)}{c\cdot(1-\rho)}$ (4)

Strength of arrivals is obtained from a simple calculation of the average value of the number of arrivals, which was measured only during peak frequencies from 6 pm to 17 pm, in the days from Monday to Friday. In the observed time period, 279 vehicles per week were weighed. In the same time period, 88 vehicles per week refueled. Therefore, the intensity of the input current – arrivals to the weighing scales is 0,1, the intensity of arrivals to refueling is 0,05. Using this data, the inputs and outputs of the queue model were calculated using equations above and are shown in Table 1.

Table 1. Results of the M/M/1 model for the weighing scale and refueling station

	weighing scale	refueling station
c = number of servers	1	1
X = arrivals (vehicles/min)	0,1	0,05
Ws = average serving time (min/vehicle)	2	5,25
Ro = utilization of servers (portion)	0,2	0,2625
C = probability, that the server is occupied (portion)	0,2	0,2625
Lq = average number of vehicles waiting to be served	0,5	0,0934
Eq = average time of vehicles waiting to be served (minutes)	2,5	7,1186

The weighting location, which is treated as server 1, has a 20% occupancy rate. The computation shows that the scale could be even more burdened is the layout of the center would allow passage past the scales. Since the occupancy of the server is less than 1 (or 100%), the likelihood that the server is busy is the same as the occupancy rate. In the case of an occupied server, the average waiting time is 2,5 minutes, the average number of waiting vehicles is 0,5.

For the server 2, the fuel tank, the situation is very similar. A distinction is made in relation to the arrivals of vehicles and occupancy of the server. The occupancy of the refueling server is 26%. Also here the probability that the server is occupied is 26% as the occupancy is less than 100%. Average number of vehicles waiting in the queue is less than 0,1. From the data it is seen that despite the smaller number of vehicles arriving to server 1, server utilization is slightly higher due to the longer serving time. All of these times are offering a reserve for optimization: if the vehicle must wait in line for refueling, the average waiting time is 7,1 minutes.

With these calculations it was proved that both servers allows for the smooth functioning of the internal logistics processes in relation to the current flow. The data gained by observations in the company show an opposite story. Drivers are losing too much time waiting for one of the servers, the weighing scale or the fuel tank, to be free. From this it can be concluded that the main reason for delays in the collection center is the incorrect placement of both servers, i.e. one directly after the other.

The collection center additionally has more circumstances which prevent the smooth unwinding of internal transport. Failure to comply with traffic regulations in the center is a major problem due to lack of space for manipulation of vehicles. Since vehicles are driving in the opposite direction on designated one-way areas, there is significant congestion and certain vehicles must recede backwards, which is not easy due to space restrictions and interruptions to other business operations. Another problem is the parking of vehicles and other means of transport in places where this is expressly forbidden.

4. CONCLUSION

More and more households and production facilities are generating and more waste, which has to be removed and managed by specialized companies. An example of such a company was discussed in this paper. The case company has a problem with internal logistics at their collection center. At present there is a lot of overcrowding, since the amount of gathered waste material is relatively large given the amount of available space. The biggest bottleneck of the collection center of the company constitutes the system of weighing and refueling the vehicles.

Currently the process of internal transport takes place so that the vehicle arriving to the center has to be weighed. The weighing scale is not necessarily free, as it can be occupied by a vehicle waiting for another vehicle to refuel due to the topology of the center where the fuel pump is located immediately behind the scale. During this time there is a possibility that a queue of vehicles forms that should be weighed or refueled.

The main problem of the paper was to identify whether there is a possibility of reducing these queues with the given parameters. The company is aware that the forming queues bring unnecessary costs, but did not know how to evaluate them. The research showed that in the case of a change of topology, the queues would more or less cease to be problematic, since the server capacities are sufficient to support the company's needs.

Moreover, some other optimization solutions exist. The first proposal is to consider outsourcing the refueling service to an external provider on remote fueling stations outside of the company. Taking into account all investment factors, fixed costs and the potential sale of the fuel pump, this solution could bring a reduction of expenses (excluding the fuel itself) of as much as 75% within five years. The following proposed solution is to update the system for weighing and data entry. In this case, the use of automatic weighing system with RFID terminal is proposed. By calculating the savings, it can be assessed that it is possible to achieve 50% cost reduction compared with the existing system within five years. Both these solutions would additionally contribute to the reduction of queuing problems at both servers and even their diminishment.

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