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# Queues at the grain store

*A study of the arrival and finishing times and amounts delivered at two grain reception points showed the typical daily routine of deliveries and how dependent the capacity of the reception point is on the amount delivered. Especially with loads delivered by farmers, improved planning of arrival times and adjustment of reception point capacity for large vehicles would achieve shorter waiting times.*

During harvest the waiting time at grain storage reception points represents an unsatisfactory break in the work flow for farmers. Recordings were carried out at two grain stores during harvest 2000 to research the basic relationships involved, and possible methods of improving the routine. At one reception point (grainstore 1) lorries were unloaded mainly and recording took place from morning to plant close-down for the day. Farmers were the main deliverers to the second point (grainstore 2) and here, timing was carried out over two days. At the latter, however, it wasn't possible to record right through to the end of the day. Performance values were calculated from the findings according to the rules of the queue theory [1, 2] listed in *table 1*. The hour was chosen as a practical time unit for the recording. To be noted is that something over two vehicles per hour were able to be dealt with at unloading point 1 and at unloading point 2 around four vehicles per hour. In all cases the term 'vehicle' represents the unit of pulling vehicle and all trailers. Before unloading (tractors as a rule on a tipping floor, lorries usually through their own hydraulics), a sample was taken to determine grain moisture content and falling number. Arrival time was taken as when the unit came to stop at the end of the waiting queue. Unloading commencement, when the unit was standing waiting to tip, or when the grain conveyor completed transporting the previous load when the plant could not run continuously because of different types of grain being delivered. In each case, the latest point of time involved was used in the calculations. Taken as end of the unloading was either the point when the grain conveyor stopped running or when the transport unit left the grainpit grid (latest point of time).

### Arrival rate and resultant waiting time

Typical for the arrival routine at grainstore 1 that almost throughout the total observation time more vehicles arrived compared with those leaving. This characteristic is demonstrated in that the value ρ is greater than 1. Notable in this case was the fact that a queue was already in existence when recording began. The queue remained during observation from 11 am to 5 pm. A complete reduction of the queue was only achieved after vehicles ceased to arrive. Before this, waiting time was up to three hours. Arrivals of the vehicles over the day were generally evenly spaced so that the reception at no time was static and with this a very high hourly reception capacity of around 50 t could be achieved.

At reception point 2 the arrival rate on day 1 and day 2 lay (*fig. 1*) as a rule below full reception capacity during the morning hours and early afternoon. On the second recording day a few vehicles had already arrived before the opening of the reception point, forming a queue by the start of the working day which was then diminished through the morning. From 4 pm on the first recording day and from 1 pm on the second, more vehicles came as were actually able to be un-

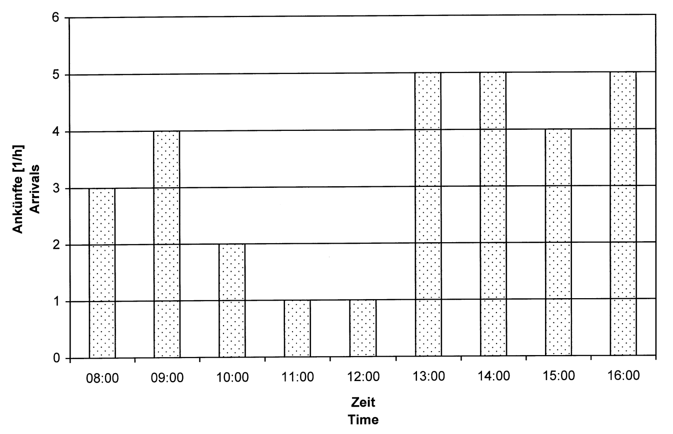


*Fig. 1: Number of arrivals over the day at grainstore 2 on second recording day*

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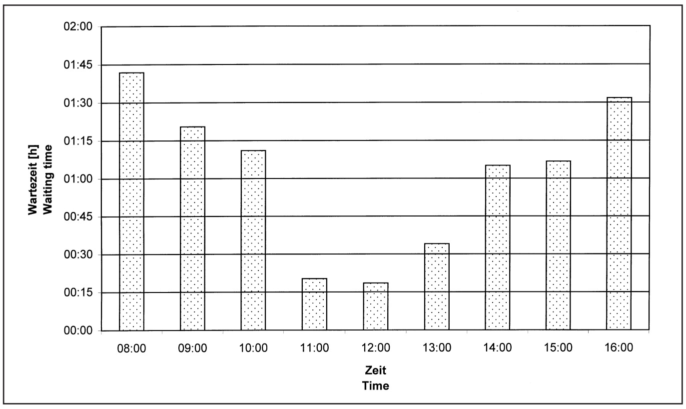


*Fig. 2: Waiting times over the day at grainstore 2 on second recording day*

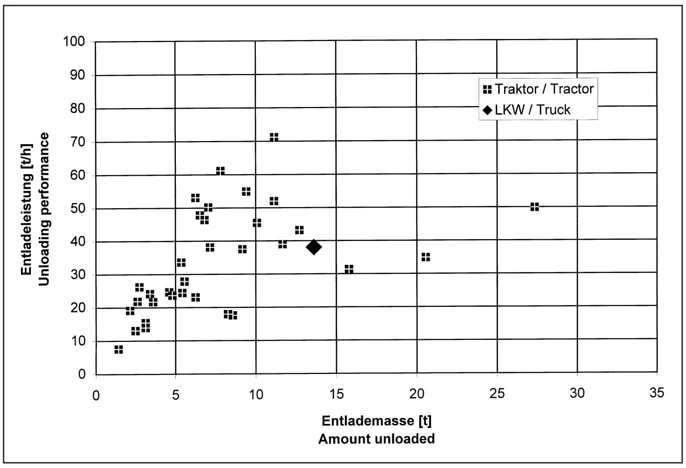


*Fig. 3: Unloading capacity at grainstore 2 in association with the amount delivered per delivery unit on second recording day*

loaded so that waiting times of up to 1.5 hours occurred. This resulted in a reduced reception capacity over the whole day (*table 1*) compared with grainstore 1, although the installed capacity was actually about the same size. The explanation for this observation is that in the morning, most of the wagons are filled with grain combined the previous evening. The farmers try to deliver these as fast as possible and accept the resultant waiting times. Afterwards, no further grain deliveries take place because there is a wait until the cereal crop in the field is dry enough before starting to combine. Then from afternoon onwards, many vehicles are once again filled and driven to the store (*fig. 2*).

### Optimising possibilities

As can be seen in table 1, the theoretical and the actual values for average waiting time and average queue length for recording day 1 and recording point 2 match one another quite well. There are already clear differences on recording day 2 which can be explained by the fact that the plant was already working at more than capacity at times and the resultant lengthening of the waiting queue could not be reduced. Because the plant was working at overcapacity calculations at recording point 1 could not be completed because then the simple queue theory failed. It therefore appeared more practical to work with simulation calculations. In order to assess available optimisation potential, a simulation calculation was carried out for day 2 in grainstore 2 wherein it was taken that the vehicles arrived at the reception point at evenly-spaced times (roughly one every 15 minutes). Within this, the recorded unloading time was retained. The result was that the maximum actual waiting time of 1.5 hours was reduced by 30 minutes and the maximum queue length reduced from six to three transport units.

| Grainstore<br>Day | 1 | 2<br>1 | 2<br>2 |
|---|---|---|---|
| Average arrival rate [1/h] | 2,6 | 2,4 | 3,6 |
| Average service time [h] | 0:26 | 0:15 | 0:14 |
| Average completion rate [1/h] | 2,2 | 4,0 | 4,2 |
| Average waiting time [h] | 2:02 | 0:40 | 1:07 |
| Average amount unloaded [t] | 22,3 | 7,3 | 7,9 |
| Average queue length | 5, 1 | 1,6 | 3,2 |
| Average unloading speed [t/h] | 49,9 | 27,2 | 33,8 |
| | | | |
| ρ (traffic density) | 1,14 | 0,61 | 0,92 |
| Probability of immediate service | | 0,39 | 0,08 |
| Average theoretical queue length | | 1,58 | 11,04 |
| Average theoretical waiting time [h] | | 0,65 | 1,58 |

*Table 1: Calculated capacities of the investigated unloading points*

### Unloading performance

The unloading performance in relationship to the size of vehicle for the second recording day at store 2 is shown in *figure 3*. When the unloading time is statistically divided independently of the unloaded amount, considerable rationalisation advantages were able to be achieved [3] through using larger vehicles and thus bundling loads together. A higher capacity tipping floor was installed at store 2. In a single operation this was able to tip units of smaller multiple wagons and large individual trailers (up to 24 t gross registered weight). Here, however, the grain conveying equipment emerged as limiting factor. Unloading charges of around 10 t could be tipped into the reception pit in a single action, but where a larger trailer was involved only the grain sides could be opened at first because the amount of grain flowing out through this was enough to fill the pit to a large extent, and this had to be conveyed away before more grain could be tipped in.

### Summary

The arrival times of farmers at grain reception points are unevenly spaced throughout the day so that capacity reserves still exist at the reception. For an optimum exploitation of the plant the size of vehicle and the capacity of the grain conveying equipment must be matched.

At times the plants were working near or over capacity, stressing the need for a strictly timed arrival of the units. To avoid longer waiting times, [1] advised exploitation of from 50 to 60%. Thus, a data communication system between plant and delivering farmers would be desirable in order to achieve an optimum exploitation of the plants (in plant 2 only half the installed conveying capacity was exploited), through permanent running of the plants and the avoidance of splitting the unloading of charges. Farmers would profit from such measures through reduced waiting times.

## Literature

Books are signified with •

[1] • *Zimmermann, W.*: Operations Research. Oldenbourg Verlag, München, Wien 1999

[2] • *Meyer, M.* und *K. Hansen*: Planungsverfahren des Oprerations Research. Verlag Vahlen, München, 1996

[3] *Parnell, C., B. Shaw* and *B. Fritz*: Systems Engineering, Operations Research and Management Science. In *Stout, B.*: CIGR Handbook of Agricultural Engineering, Vol III, Plant Production Engineering. ASAE St Joseph, MI, 1999, pp. 521 – 536