SIMULATION AS AN ESTIMATING TOOL

by

Gerda Woxen
IBM Nordic Laboratory
Stockholm, Sweden

SUMMARY

The advantages of using the simulation technique as a tool to estimate performance of systems will be discussed and illustrated by some simulations performed by Swedish industries.

"Should double tracks be used, or would single tracks perhaps be sufficient in some parts of a mine?" was a question raised by a mining company when making preparations for a project. To investigate the utilization of the tracks and estimate the queueing tendencies in the different regions, a model was designated and simulated with the GPSS, General Purpose System Simulator.

Another problem of perhaps common interest is the simulation of the traffic in an oil harbor, which was done in order to estimate its utilization during the next ten years, and thus make it easier to predict the appropriate time to enlarge its facilities. The model, which was a somewhat simplified representation of reality, made it possible to study the influence of various parameters on the queueing situation in the harbor.

THE MINE PROBLEM

A mining company was planning a new mine when the question of what transportation system to use had to be decided, if trackbounded traffic was to be used. Would it be possible to cut down the costs by using single tracks in those parts of the mine with low-traffic density?

The question couldn't be answered directly by hand because so many different situations could arise in the mine and because all facts and circumstances involved had to be considered if a somewhat close estimate were to be given. By describing the problem in a simulation language, however, and having a computer keep track of the situations and relationships, a better idea was obtained about the queueing situation and the utilization of the tracks in different parts of the mine. Some of the assumptions made about the mine will be recalled first. A discussion of the model itself, together with some of the properties of the simulation language, GPSS, will follow.

The mine was designed to have two major sections serviced by two separate transportation lines, but with the weighing stations and unloading stations in common for the one. The amount of metalliferous rock in each mining area had earlier been estimated, and could, in the model, be used to direct the number of trains to a region in proportion to the amount of ore contained. Two types of trains were used in the mine: trains for transportation of metalliferous rock, called "ore-trains," and the somewhat smaller trains carrying tools and materials for the workers, called "material trains." The speed varied for the ore trains depending on whether or not they were loaded, while the material trains were considered to run at a constant speed.

Simulation of Traffic in the Mine

The material and ore trains busy in the mine correspond to the so-called "transactions" in the GPSS language. With each transaction are a number of connected parameter fields, which describe its properties and characteristics. In this case, the type of train -- material or ore -- its length, and speed, were kept in those fields, and the content tested when decisions (e.g., what route or action to take) had to be determined. Also, information regarding how much time a train had been busy in a shift or how much time a trip to fetch ore took were kept as parameters so some statistical information about the times and the standard deviations could be calculated.

To check how much the tracks were used in different areas in the mine, the tracks were divided into smaller sections -- so-called "storages" in GPSS -- with each section, depending on its length, capable of simultaneously servicing a number of trains. With the speed of the train stored in a parameter, and the length of the section known, the time each train spent in a section was calculated and accumulated in order, at the end of the simulation, to make calculations possible of the total utilization of that section.

When a queue arose enroute to a mining area, the time spent on the queue was registered. A queue could arise even where double tracks were used in the mine, if a train, in order to enter a mining region, had to cross the opposite track being used by an oncoming train. After arriving at the intended mining region, the trains spent varying times there, depending on the type of train and the amount of work to be done. The times were received by choosing a number at random from previously constructed distribution functions. Before leaving the mining region, tests were performed to check that the return track could be entered without risk of collision with any oncoming trains.

The ore trains were then weighed at one of the two different weighting stations. Queues could arise in front of the station because their capacity was limited. A driver could, however, check the conditions at the weighing stations. If the nearest-situated station was busy, he would decide to drive to the other station. Similar conditions existed at the unloading stations, where the driver also had the opportunity to choose the most suitable one.

Figure 1 is a simplified flowchart of the model.

Figure 1 Flow

1. Start a shift.
2. Start the trains according to a rectangular distribution function.
3. Choose section and region at random according to the estimated amount of ore in the areas.
4. Drive to the mining region. Register if waiting time in queues occurs on the route.
5. Check if opposite track has to be crossed without risk in order to enter the mining region.
6. Load the train.
7. Check if feasible to use the track and drive to the weighing station. All oncoming trains on that track have to be beyond a certain distance.
8. Drive to the weighing stations.
9. The material trains can drive directly to the turning place.
10. Wait in a queue before weighing, if necessary. Weigh ore.
11. Check if there is a free place at the nearest unloading station. If all are busy, try at the other station.
12. Unload.
13. Wait in the queue if turning place is busy. Turn.
14. Is it at the end of the shift or almost at the end?
15. Go home.

The following relationships were shown from the simulated mine model:

-- How many material or ore trains that had visited the different mining sections.

-- The average time the trains had spent on a tour and in a shift.

-- Where queues had occurred. A queue could, for example, have been on any of the track sections, at the weighing stations, or at the unloading stations. The percentage of trains delayed because of a queue, and the average time it had spent in a queue, were specified.

-- How high the utilization of the different track sections had been.

-- Whether or not and how often the two tracks in the same section of the mine had been busy simultaneously.

The last two items were particularly important in determining whether single tracks would be conceivable and where they should be located.

THE HARBOR PROBLEM

There were two types of loading quays in the harbor. Quay 1 and Quay 2. They had identical facilities, except that Quay 1 could provide the service required for ships carrying a special kind of oil. As that quay, however, was more conveniently located than was Quay 2, as many as 75% of the other ships initially tried to use Quay 1. If, however, Quay 1 was busy, the Quay 2 was chosen if unoccupied. When both quays were busy, the ships had to wait in a queue until either one of the quays was available, at which time they were served on a first-in, first-out basis.

The ships arrived in the harbor at intervals depending on the season of the year and whether it was day or night. During the winter months -- October to March -- bad weather or icy conditions could, for example, cause delay with a specified probability. Some of the ships that would arrive at the harbor during the night chose to adapt their speed and instead arrive at dawn. A day was, in the simulation, regarded as having 14 hours of daylight and 10 hours of darkness, with all the navigation difficulties this entailed.

When a ship arrived at a quay, it stayed there without interruptions until all oil was unloaded and until complementary work had been completed. Then it immediately departed (extra time at quays due to rest or repairs was not considered). Sundays and public holidays were eliminated from the year as no work would be performed during those days. A year, therefore, consisted of 12 months, each containing 25 workdays, which makes a total of 300 days.

Simulation of Traffic in the Harbor

A simulation study of this size, where complex relationships are present, makes manual calculations almost impossible, because there is a demand for as great a resemblance with reality as is possible. In this case, the simulation language GPSS was used and the calculations were performed on an IBM 7044.

The model consisted of a system of blocks with different characteristics through which the generated "ships" passed or did not pass depending on outcomes of tests performed in the preceding blocks. The simulator kept account of the ships, their location, the time they spent in the model, etc. Also the times spent in queues or during usage of a harbor facility were registered, so that the average time and utilizations of the quays were printed in the results.

The block diagram in Figure 2 shows the model in a simplified form with the alternative paths that could be chosen. The model also included some supporting sections not shown on the figure, which is limited to information about year, season, and time of day.

Figure 2 Flow

1. The ships are generated with an interval T of $T = A \times E \times M$ where A is the average arrival frequency, E is a value chosen at random to adapt the intervals to a negative exponential distribution, and M is a factor varying with month of the year.
2. Functions based on statistics from preceding years and prognosis for the future are used to choose the size of ships, and the amount and different kinds of oil.
3. Different paths are used in the diagram, depending on whether the season.
4. Test if it is day or night.
5. A percentage of the ships would rather wait for the dawn than navigate in the harbor at night.
6. Wait for the dawn.
7. Is the weather good enough for landing?
8. Enter the queue if the quays are busy.
9. Is it an oil type that has to be unloaded at Quay 1?
10. Wait until Quay 1 is free.
11. A percentage of the ships always try to unload at Quay 1 if it is empty; if not, they try Quay 2.
12. Unload when a quay is available.
13. Unload the oil.
14. Leave the harbor.

Results of the Harbor Simulation

A number of simulations were performed with the model before any conclusions were drawn from the result, because the many random variables involved caused great variances. The model also included a cost calculation based on the amount and kind of oil the ships carried, multiplied by the waiting time in a queue. This was done in order to give an understanding of the additional costs caused by a delay and by a shortage of harbor facilities.

In the results, an upward trend of costs was noticed in the later years of the simulated period, but the next few years did not seem to cause any problems. It was, however, decided to collect more statistics during the coming years in order to update and estimate the functions in the model more accurately and to then repeat the calculations at a later time.

SUMMARY

Simulation methods have been very useful in the study of complex systems such as the train and ship examples. With a mathematical model representing the problem, an estimate of the real system's performance and characteristics is facilitated. We must, however, remember that the solution cannot be better than the model itself. Consequently, the model must be a good representation of the system; so the question of whether all necessary and sufficient factors are included has to be checked before decisions are drawn based upon the results.

BIBLIOGRAPHY

H. Herscovitch and T. Scheider, "GPSS III - An Expanded General Purpose Simulator," IBM Systems Journal, Vol. 4, No. 3, pp. 174-183, 1965.

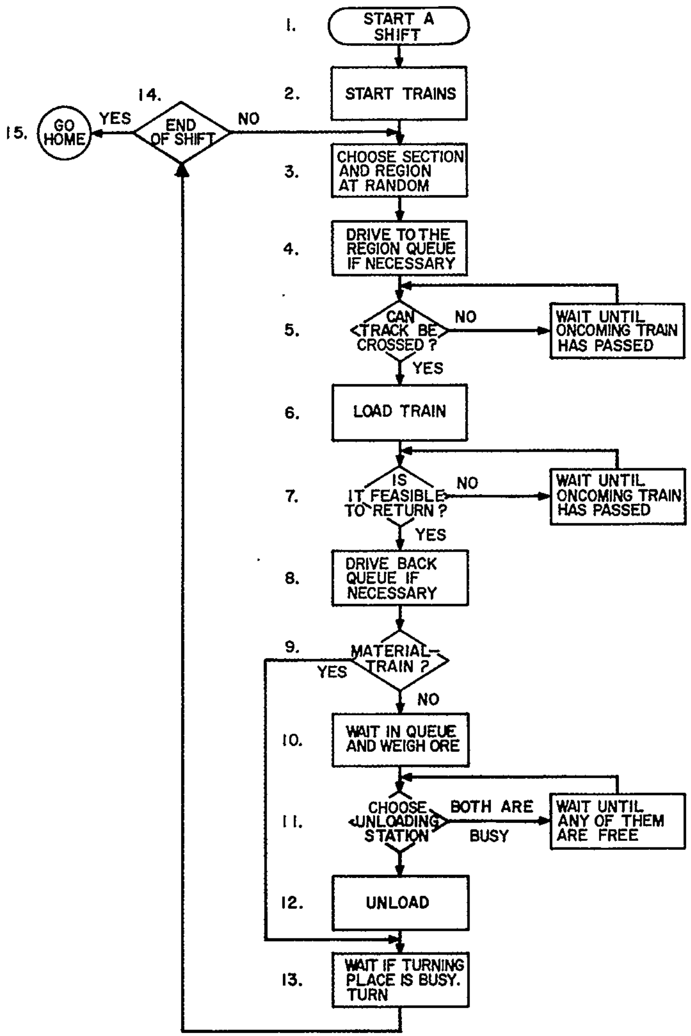

Figure 1. Train simulation.

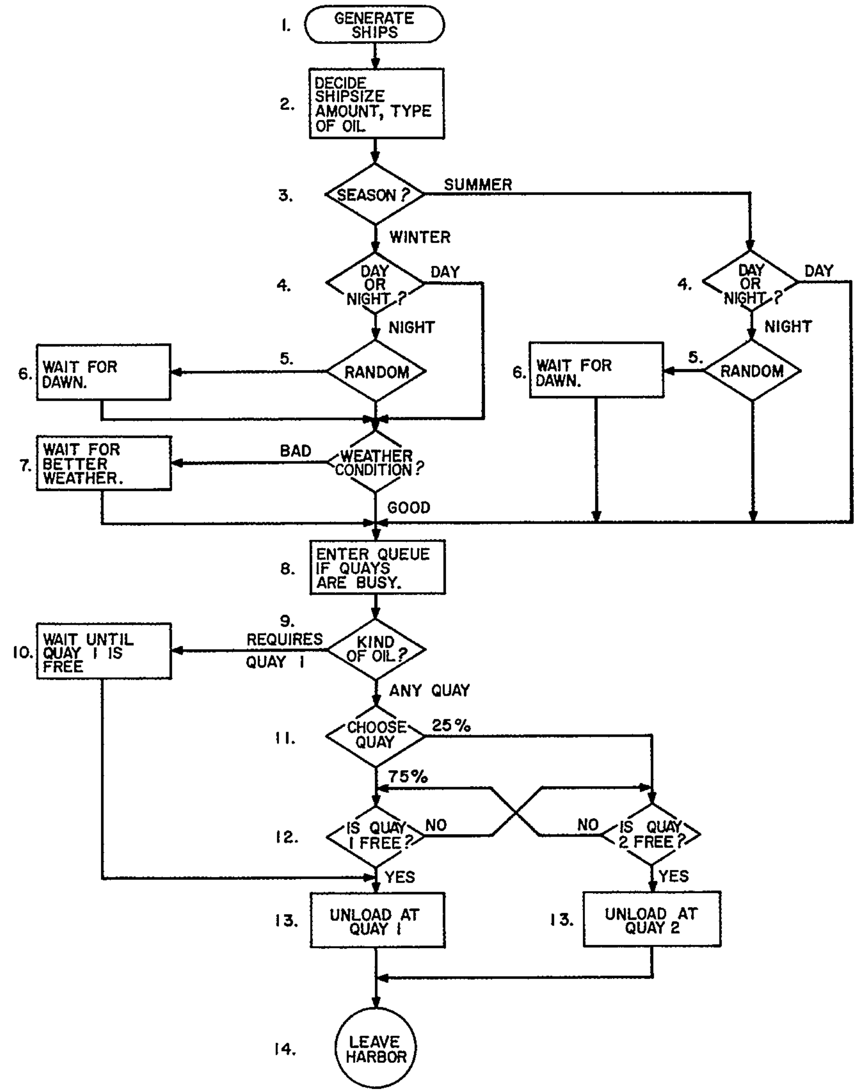

Figure 2. Harbor Simulation.