GENERALIZED GPSS MODEL FOR GRAIN TERMINAL ELEVATORS

J.E. Peterson
Institute for Computer Studies
The University of Manitoba
Winnipeg, Manitoba, Canada

PREFACE

The generalized GPSS Model for Grain Terminal Elevators, also referred to as the Grain Terminal Simulation (GTS), unites well-defined rules of notation with a generalized, GPSS simulation program to yield a complete system for the specification and simulation of grain terminal elevators. The original development goals of general applicability, relative ease of evaluating varied policies and configurations and ease of use, have to a significant degree, been achieved.

INTRODUCTION

The Grain Terminal Simulation was developed to provide the Canadian grain industry and, specifically the operators of terminal elevators, with a means of evaluating existing and future terminal operations. The grain industry in Canada as elsewhere, begins with the producer or farmer seeding, then harvesting grain in the prairie regions, harvested grain is stored in regional country elevators operated by grain handling companies and co-operatives.

National and international sales of grain initiate movement of stored grain, by train, to ports capable of loading Great Lakes and ocean-going ships (Figure 1). Grain trains arrive at the terminal elevators of these ports to be unloaded, the grain is stored and loaded into ships when they arrive.

A major problem in the Canadian grain industry exists because the port facilities of the Lakehead and Churchill have restricted shipping seasons. Therefore, there is a critical need to maximize total grain throughput at each terminal of these and other supporting ports. During a representative shipping season at the Lakehead, which has a total storage capacity of over one hundred million bushels, approximately ten times this volume would be shipped. Most existing terminals were constructed in the early nineteen-hundreds and although equipment modifications have been made since then, increased efficiency is greatly desired.

THE TERMINAL ELEVATOR

The basic functions of a terminal elevator include boxcar or hopper car unloading, weighing, cleaning, drying, storing and shipping of grain (Figure 2). Each function is fulfilled by specific, function oriented equipment groups, automatic dumpers or manual shovels, hopper scales, batteries of cleaners, dryers, cylindrical storage bins, and shipping spouts (Figure 3). The movement of grain as it is processed through these functions is affected horizontally by conveyor belts and vertically by belts fitted with scoops, these belts called "legs".

The existence of commonalities among terminals has allowed the consideration of the overall terminal operation in main stages or operations. These operations are:

1. Receiving - the unloading of trains and weighing of grain;
2. Cleaning - cleaning and re-cleaning to achieve a defined level of cleanliness;
3. Drying - drying and re-drying until a defined level of dryness exists;
4. Storage - storage of grain in large "annex" bins;
5. Shipping - weighing and movement of grain into ships;
6. By-product Processing - movement and storage of by-products.

REQUIREMENTS OF THE GRAIN TERMINAL SIMULATION

To the extent of the basic functions, terminal elevators are similar, however, from the equipment, its configuration and characteristics to the policy decisions governing equipment use, each terminal is unique. With this in mind then, the requirements of the Grain Terminal Simulation were defined to be:

1. adaptability to varied equipment configurations and characteristics within a defined functional structure for a single terminal with a view to multiple terminal simulation;
2. provision to evaluate varied grain processing and storage policies; and
3. an easily used system requiring no specialized programming knowledge by the terminal operators.

In general terms, GTS may be described as consisting of a method of notation with which to define a given terminal and its operation and, secondly, a program[1] to simulate the defined terminal model and its characteristics.

MODEL DEFINITION

The definition of the physical model of a terminal elevator is accomplished using a simple flow-charting technique followed by a well defined procedure to describe the flow-chart to the simulation program. A scheme of numbering the blocks, representing equipment, and the block-joining arrows, representing valid movements of grain (Figure 4) allows the physical characteristics of the elevator to be expressed in numerical tables or matrices and two dimensional graphs (Figure 5).

Operating policies regarding the way in which grain is moved through the processing stages, rules describing the degree of equipment dedication to various functions, and the priorities of competing functions are also defined in matrix form. The specification of the grains to be considered in the simulation and the boxcar and ship arrival functions follow the same pattern of notation. This information is coded onto forms, keypunched and inserted into the simulation program.

SIMULATION PROGRAM

The GTS program is divided into two main sections. The first section basically performs a non-simulation function, whereas the second actually simulates time and processing. These differences are considered in more detail.

The first section performs the following operations:

(a) generation of transactions, some representing grain cars and ships, others performing scanning operations which under certain conditions, initiate grain movements;

(b) the planning of the routes the grain will follow through the terminal from a known source area to a known destination area (Figure 6).

Several of the basic operations performed in the phase of route planning become cumbersome in GPSS. Except for the generation of transactions, representing ships and trains, the majority of actions are centered around the scanning, modification and construction of matrices or tables and the updating and referencing of counters. The sub-sections of this first section are:

1. Grain movement initiation by ship or train arrivals or by the detection of pre-defined conditions, during matrix or table scanning.
2. Identification of the required processing, and identification of the primary and secondary destinations and sources in terms of equipment groups as well as the actual equipment.
3. The construction of tables (matrices), each column containing numbers of the groups through which grain must flow to reach its desination.
4. The construction of tables representing tree structures, each node being a piece of equipment through which grain may pass to reach its destination.
5. The analysis of the tree structures to consider the degree of equipment dedication for each equipment group relative to the priority of the basic function being performed.
6. Analysis of the status of the equipment represented in the tree structures with a view to the pre-emption of equipment where the relative priorities of competing functions justifies.

[1] The simulation program uses the General Purpose Simulation System language.

The result of these sub-sections is a matrix in which is stored all valid forests[1] of routes which grain may follow from source area to destination area.

The forests of routes defined in the first section become the basis of operation for the second section. In this section, grain is moved along the forests of routes simulating time, processing and storage as the grain transactions enter and leave the devices represented by the nodes or numbers of the forests. The sub-sections of the second section are:

1. Depending on the last entity that a transaction entered, several next valid entities are chosen from the corresponding route forest. From these valid next entities one is chosen.
2. For this entity, grain entry, processing time and processing modification are simulated.
3. Repeat cycle.

VARIANCE OF TIME

The total simulated time of an operating terminal can be varied, by the user, in the standard GPSS manner. The number of hours per day that the machines of each equipment group are simulated can be varied allowing for the inclusion of overtime simulation in some sections of the terminal to the exclusion of others. Simulation of the terminal operating with equipment breakdown is also possible and does not require changing the basic configuration definition cards.

[1] For the purpose of this description, the term "forest" is used for the matrix representing several route tree structures.

OUTPUT STATISTICS

The output of a simulation reveals the standard GPSS equipment statistics. From these, bottlenecks and other problems are evident. In addition to the standard statistics, information concerning train arrivals and train characteristics, ship arrivals and departures, and pertinent statistics for ships and for grain shipped is included. Grain throughput, as a total, and for each grain type are other useful outputs.

SUMMARY

In summary, GTS provides the grain terminal operator with a useful tool for evaluating existing operations, proposed structural changes and the comparison of competing grain processing policies. Although GTS does not require a user to be familiar with GPSS, a detailed knowledge of the terminal and its policies is essential.

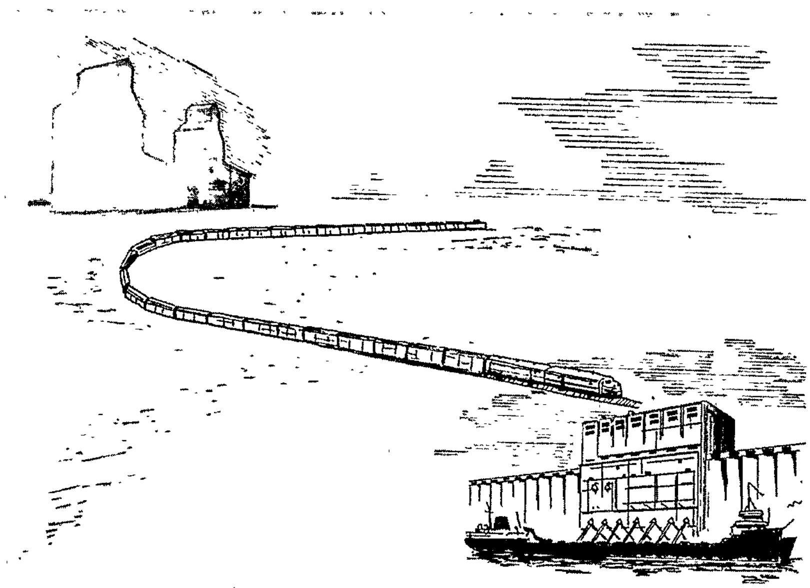


Figure 1 - GRAIN MOVEMENT FROM COUNTRY ELEVATOR TO MARKET

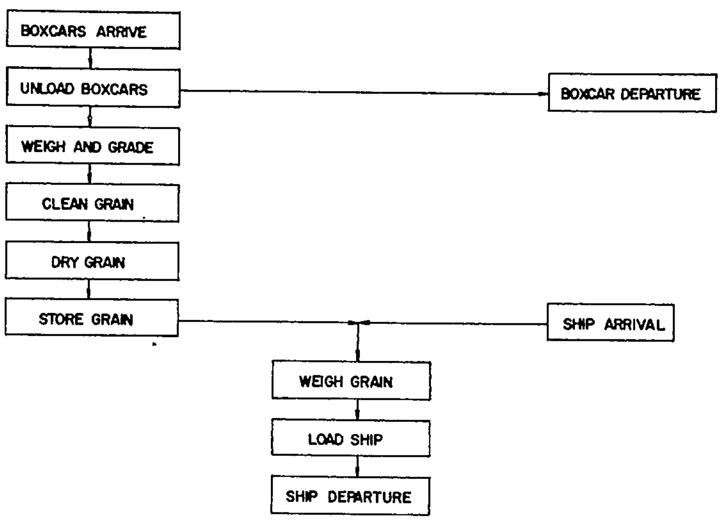


Figure 2 - FUNCTIONS OF TERMINAL GRAIN ELEVATOR

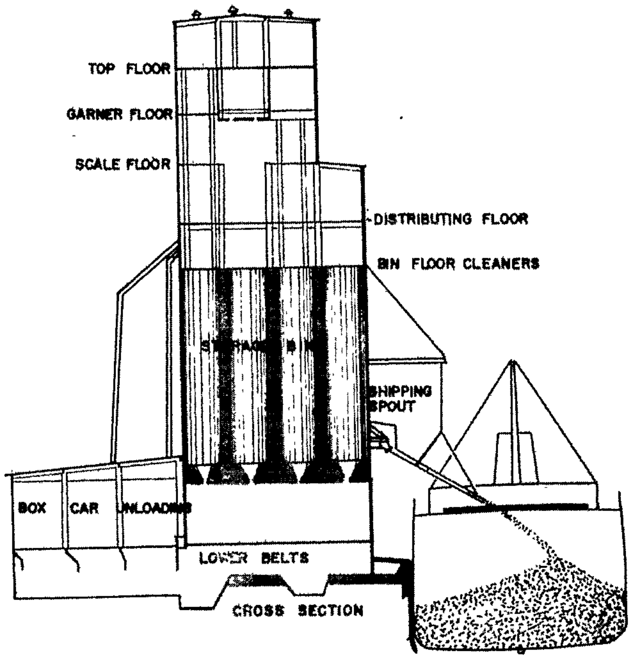


Figure 3 - CROSS-SECTION OF TERMINAL GRAIN ELEVATOR

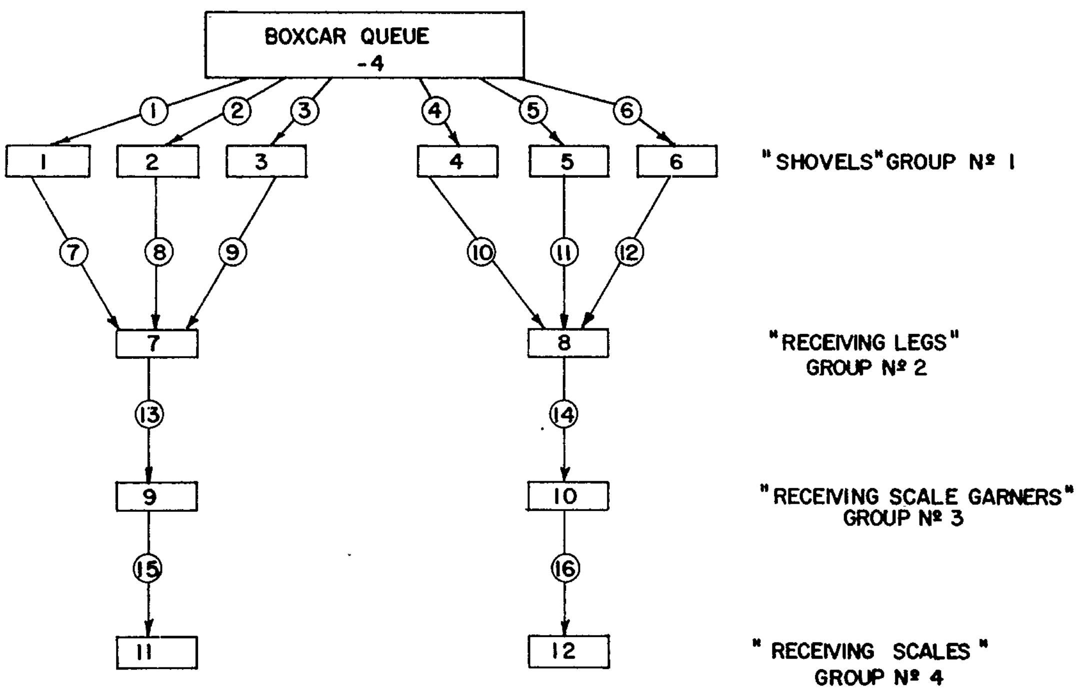


Figure 4 - RECEIVING OPERATION WITH NUMBERED ENTITIES AND PATHS

FUNCTION 1
ENTITY-GROUP IDENTIFICATION

ENTITY Nº →	GROUP Nº
1	1
2	1
3	1
4	1
5	1
6	1
7	2
8	2
9	3
10	3
11	4
12	4
⋮	⋮

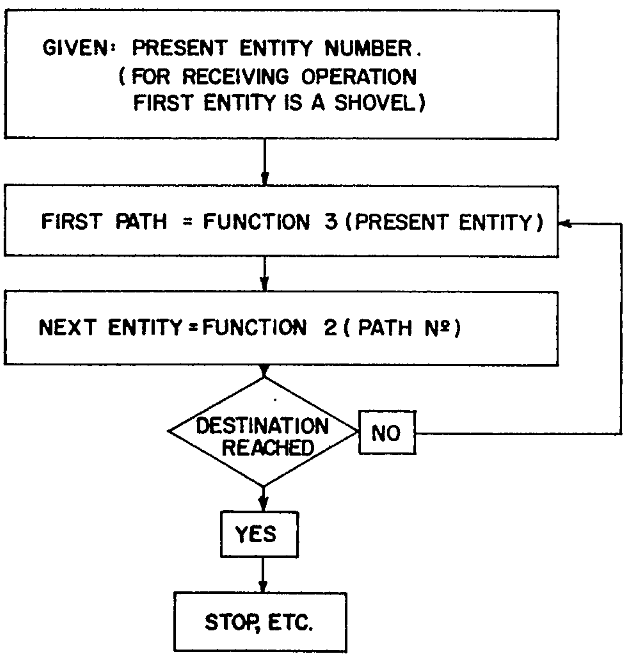
FUNCTION 2
PATH-ENTITY IDENTIFICATION

PATH Nº →	ENTITY Nº
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	7
9	7
10	8
11	8
12	8
13	9
14	10
15	11
16	12
⋮	⋮

FUNCTION 3
ENTITY-FIRST PATH IDENTIFICATION

ENTITY Nº	FIRST PATH
1	7
2	8
3	9
4	10
5	11
6	12
7	13
8	14
9	15
10	16

Figure 5 - ROUTE PLANNING FUNCTIONS OR TABLES



EXAMPLE

FIRST ENTITY IS Nº 3
FIRST PATH = FUNCTION 3 (3) = 9
NEXT ENTITY = FUNCTION 2 (9) = 7
FIRST PATH = FUNCTION 3 (7) = 13
NEXT ENTITY = FUNCTION 2 (13) = 9
FIRST PATH = FUNCTION 3 (9) = 15
NEXT ENTITY = FUNCTION 2 (15) = 11

Figure 6 - ROUTE PLANNING PROCEDURE