Proceedings of the 1987 Winter Simulation Conference
A. Thesen, H. Grant, W. David Kelton (eds.)

SIMULATION OF CONTINUOUS MAIL PROCESSING

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ABSTRACT

Simulation may be used to determine the number of sorting devices needed in an automated postal system facility. The model must deal with mail types with great variability in processing characteristics. Interactions, at the sorting stations, between continuously and sequentially processed batches of mail of these different types, introduces a bias in conventionally collected statistics. Although the logic of the basic simulation is straightforward, the model must be significantly modified to produce unbiased or undistorted statistics. SIMNET and SLAM II are used for independently developed final models.

1. INTRODUCTION

Anticipating the processing of 240 billion mail pieces a year by the year 2000, applications of new technology and innovative ways of handling mail have become critical issues. Mail sorting forms an important function in the postal operation system. Small per piece reductions in sorting times could significantly reduce the annual operating costs of the U.S. Postal Service. Efforts have thus concentrated on automating the sorting process as much as possible.

Automatic sorting involves the use of bar-code reader/sorters (BCRS), optical character readers (OCR) and video key entry stations with directory lookups (VKES). The specific sequence required to sort a piece of mail depends on the quality of the mail. For example, a major portion of bar-coded mailpieces is sorted efficiently by BCRS. On the other hand, mail collected from local mail boxes must be processed either by the OCR or manually.

Simulation may be used to determine the number of sorting devices needed in a typical postal facility. Normally, the development of the simulation model would have been straight- forward if each type of mail is simulated independently. This is not the case in a typical sorting operation. Specifically, the model is complicated by the fact that mail types are run in batches and that each mail type has its own level of quality and "accept/reject" rates for automatic processing. As such, the utilization of the sorting devices depends on the batch being processed. For example, bar-coded mail makes extensive use of BCRS, where as other types of mail will rely heavily on the use of the OCR and VKES.

Interaction between the various types of mail occurs since a new batch is started immediately after the last piece of mail from the preceding batch has been introduced into the system. The result of this interaction together with the fact that batches of mail of different qualities are processed sequentially leads to a bias in the collection of pertinent statistics. For example, if the bar-coded batch is much larger than the batch that utilizes the OCR, the average utilization of the OCR will tend to be smaller than it should be since the utilization is based on a time interval that is inflated by the duration needed to process the bar-coded batch. The bias in collecting statistics necessitates that the simulation model be modified to account for this bias. This point is the focus of the development in this paper.

2. POSTAL SYSTEM DESCRIPTION

A schematic representation of the pertinent mail processing flow is given in figure 1. The postal facility processes three types of mail batches: (1) incoming mail from other post offices, (2) local metered (first class and third class) mail, and (3) local collection mail.

Incoming mail is run through a BCRS to read bar-codes that may have been put on the envelopes by the originating post offices. A small percentage of this mail may not be coded properly, and hence requires further processing on the OCR sorter.

Metered and third class mail is fed directly into the OCR sorter, although the metered mail may have a small percent of hand addressed mail.

Collection mail is run through an enricher that separates handwritten mail from machine printed mail. It also separates poor quality machine print which would have a low probability of being read by the OCR sorter. The low cost of the enricher compared to the OCR makes this feasible.

In each mechanical operation, a small percent of the mail is rejected and transferred to manual-processing because of the unacceptability for further mechanical processing.

The mailpieces from the three streams reach the OCR for attempted read/sort operations. The BCRS will sort all pieces

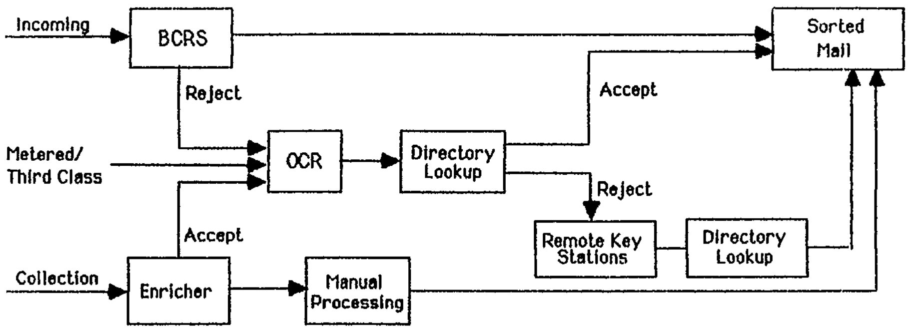

Figure 1: Mail Processing Flow

with bar-codes and will reject to the OCR all mailpieces without bar-codes. At the OCR, an attempt is made to read and sort the mailpiece. If the reading is successful, the mailpiece will be sorted. If the reading is not good enough to sort the mailpiece, an image of the piece is transmitted to a series of video key entry stations where human operators will view the video and key in the characters not read in by the OCR. The number of keystrokes required to complete sorting is a function of the OCR read rate, which in turn is a function of the mail stream being processed. A maximum of 14 characters read and/or keyed is required for a successful sort. Indeed, the number of keystrokes needed on a mailpiece is a random variable from 1 to 14 with a skewing factor on the distribution which is a function of the mail stream being processed. Because of the lack of specific data that allow identifying the correct distributions, the triangular density function is assumed to represent the keystroking operation. Figure 2 provides the distributions as a function of the different types of mail.

3. MODES OF OPERATION

Mail types are run in batches; typically incoming, then metered, and then collection. The overall performance with various mixes of these mail streams is important. Additionally, each mail type has its own level of quality and accept/reject rates for automatic processing. In this study, it was necessary to assume batch sizes and sequence, values for accept/reject rates at the BCRS, OCR, and enricher, and other operating parameters. Those assumptions are described in the following paragraphs.

The accept rate for incoming mail at the BCRS is 90%. At the OCR, each mail stream has its own accept ratio as summarized in Table 1.

Table 1. OCR Accept Ratios by Mail Type

Mail Type	OCR Accept Ratio
Incoming	.75
Metered	.70
Third class	.61
Collection	.61

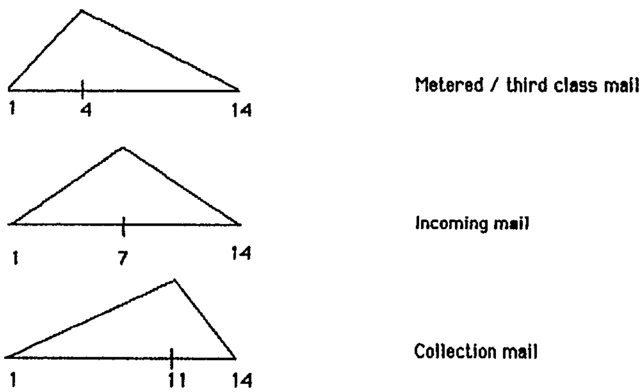

Figure 2: Distributions Describing Number of Key Strokes as a Function of Mail Type

It is estimated that 90% of the collection mail will be passed by the enricher to the OCR. The remaining 10% must be sorted manually.

The total system throughput is 10 mailpieces per second. By staging the different types of mail with individually defined quantities, one can simulate any mix of mail. The sequence and time of arrival of each type mail batch constitutes an important factor. For this study, the question to be answered resolved to "can the composite mail stream be processed by a given shut off time and how many key operators (video terminals) should be provided as a function of the time of day".

4. DEVELOPMENT OF THE SIMULATION MODEL

The development of the simulation model is straightforward. It follows the block diagram in Figure 3. The nature of the postal system as summarized in Figure 1 suggests that network simulation is the most suitable tool for modeling this situation. Initially, the system was modeled in SLAM II network simulation. However, preliminary runs indicated that collected statistics, as will be explained below, are grossly biased. This bias has nothing to do with the logic of the developed SLAM II model. Rather, the nature of the developed system has dictated this bias. As a consequence, it proved necessary to redevelop the model in order to collect undistorted statistics for an optimum number of key stations required for the integrated system. Two alternatives were available: (1) modify the preliminary SLAM II model using user-written FORTRAN inserts to collect the required statistics and (2) develop a new model using SIMNET network simulation language with which the desired statistics could be gathered directly without the need to use FORTRAN inserts. It was also noted that using SIMNET would have the advantage of providing independent results which, if congruent with those from SLAM II model, would give confidence to the results.

In order to appreciate the degree of distortion in statistics collection, consider the operation of the BCRS and OCR and assume that only incoming and metered/third class mail is handled. Incoming mail makes high use of the BCRS and rather limited use of the OCR and the key stations. On the other hand, metered/third class mail follows the exact opposite pattern. Since computing the utilization of the video key stations for a given mix of incoming and third class mail is of interest, a typical variation with time of this utilization may appear as shown in Figure 4.

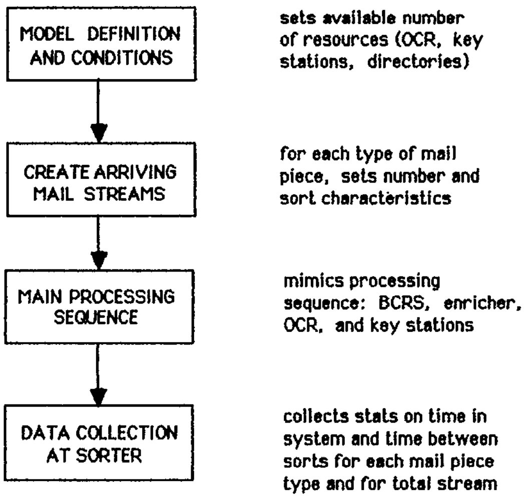

Figure 3: Block Diagram of Network Model

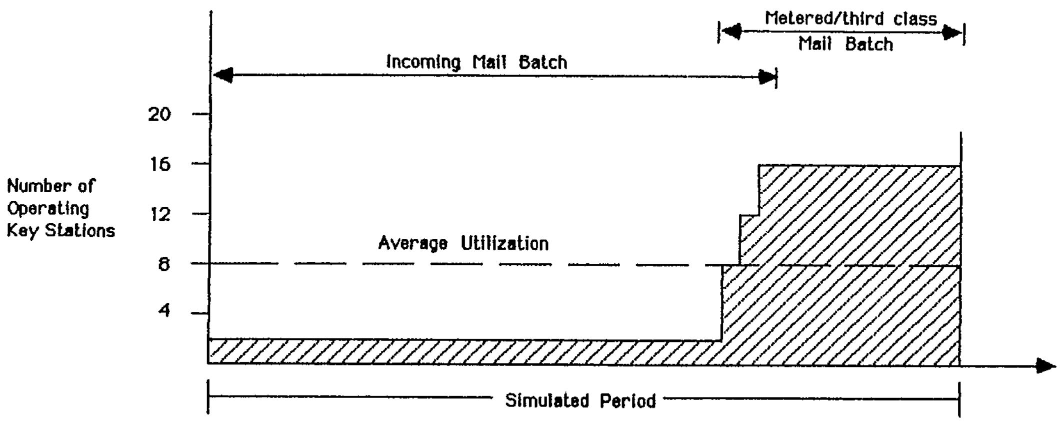

Figure 4: Collection of Statistics for the Model

Since incoming mail makes very little use of the OCR, the number of operating key stations is expected to be low while the incoming mail batch is being processed. This utilization should increase appreciably when the processing of metered/third class mail begins. Since the two batches are processed in a single simulation session, the average utilization of key stations should appear much lower, particularly if the incoming mail batch is large relative to the metered/third class mail batch. In other words, the average utilization computed in this manner will not reflect the true nature of the drastic variation in the use of key stations.

Different types of mail can be modeled as being processed independently. This type of model, however, would not be accurate since it ignores the interaction between the different batches, particularly when it comes to studying the effect of various processing sequences on the output of the model.

In order to maintain the effect of interaction among mail types in the model and, simultaneously, collect the statistics that reflect each mail stream, the models are modified to allow the user to compute the desired statistics "manually". In essence, instead of using one variable to represent a given statistic during the entire simulation period, one can now associate three different variables (corresponding to the three types of mail) with each desired statistics. This procedure is illustrated by computation of the number of operating key stations.

Define the variables representing the number of key stations associated with incoming, metered/third class, and collection mail as:

```
INCOM STNS
MTRD STNS
COLL STNS
```

Figure 5 shows the time domains associated with each variable during a typical simulation run. It is assumed that the three mail batches are processed in the order in which the variables are listed. Notice the overlaps in the time domains, which is the result of the interaction between the three different types of mail.

The idea of the procedure is to confine the collection of statistics for each variable to its designated time domain. Specifically, provisions must be made to compute the areas A1, A2, and A3 as defined in Figure 6. At the end of the simulation run, the desired time-integrated averages of the three variables as A1/T1, A2/T2, and A3/T3 values, respectively, are computed where T1, T2, and T3 are the time periods for the three variables.

The following sections illustrate the use of both SIMNET and SLAM II to collect the data (A1, A2, A3, T1, T2, T3) defined in Figure 6. A basic difference between the two languages is that the desired information can be obtained in SIMNET without the need to use external FORTRAN subroutines. In SLAM II, however, the use of user-written functions appears to be the most efficient approach.

5. SIMNET STATISTICAL PROCEDURES

In SIMNET, the procedure starts by defining the following variables:

```
$VARIABLES:  INCOM STNS;TIME.BASED;W(1,1):
             MTRD STNS;TIME.BASED;W(1,2):
             COLL STNS;TIME.BASED;W(1,3):
             INCOM PERIOD;OBS.BASED;W(2,1):
             MTRD PERIOD;OBS.BASED;W(2,2):
             COLL PERIOD;OBS.BASED;W(2,3):
```

This means that the variables and their time periods (i.e., T1, T2, and T3) are computed by using SIMNET's double scripted variable W. In order to ensure that each variable is collected only during its time domain, SIMNET uses the following conditional statement to calculate the statistics for the time based variables:

```
IF, A(1)=1, THEN, COLLECT=INCOM STNS, ENDIF
IF, A(1)=2, THEN, COLLECT=MTRD STNS, ENDIF
IF, A(1)=3, THEN, COLLECT=COLL STNS, ENDIF
```

These statements recognize that attribute A(1) assumes the values 1, 2, and 3 depending on the type of mail. Notice that W(1,1), W(1,2), and W(1,3) are used to keep track of the number of operating key stations.

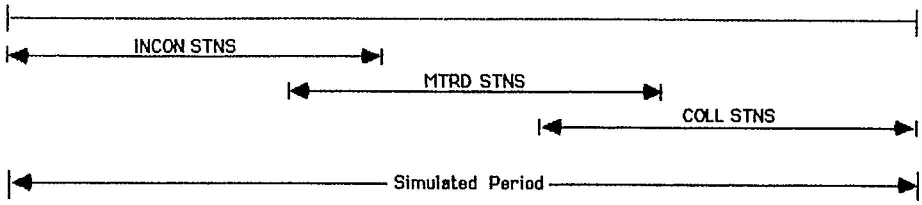

Figure 5: Collection of Statistics by Mail Type

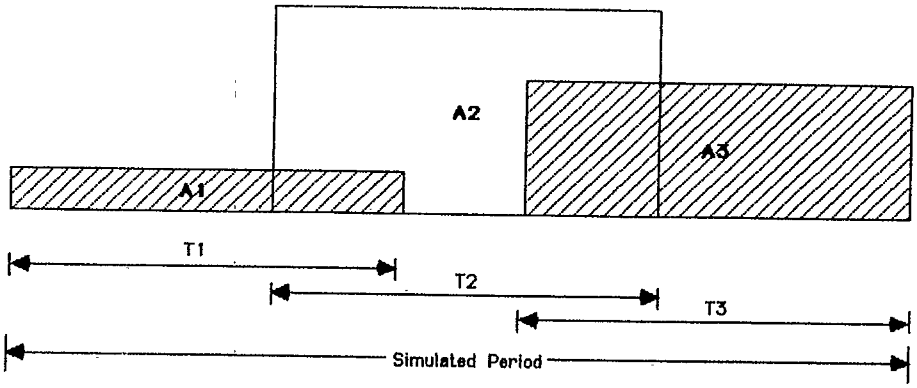

Figure 6: Procedure for Collecting Statistics

The variables INCOM PERIOD, MTRD PERIOD, and COLL PERIOD are used to compute T1, T2, and T3 as defined previously. In particular, the variables W(2,1), W(2,2), and W(2,3) are set to zero at the instant a respective batch starts processing. When the last mailpiece of the batch is sorted the associated W(2,1), W(2,2), or W(2,3) is then set equal to the current simulation time and the variable statistics is collected. As such, each of these variables will be collected exactly and its "mean" value will equal T1, T2, or T3 as desired.

At the end of the simulation, SIMNET will automatically produce the mean values of the time-based variables INCOM STNS, MTRD STNS, and COLL STNS. These mean values are automatically averaged over the entire length of the simulation run rather than over the designated time domains T1, T2, and T3. We can correct this bias in the following manner, however. Let T represent the entire length of the simulation run. By the definition of time based variables, one observes that

A1=Tx(mean value of INCOM STNS)
A2=Tx(mean value of MTRD STNS)
A3=Tx(mean value of COLL STNS)

Hence, the unbiased mean values can be computed by dividing A1, A2, A3 by the values of INCOM PERIOD, MTRD PERIOD, and COLL PERIOD as provided by SIMNET.

6. SLAM II STATISTICAL PROCEDURES

Several SLAM II functions are available which usually provide statistics for resource utilization, notably RRAVG(IRSC), RRSTD(IRSC), and RRPRD(IRSC). These functions do not, however, provide a mechanism for differentiating between resource utilization by different entity types.

Separate resource blocks must therefore be defined for each mail type. Statistics can then be collected using the conventional SLAM II functions of RRAVG, RRSTD, or RRPRD. However, to maintain the interaction of mail types, the number of resources available in each resource block must be altered up or down in such a way as to keep the total available to the system a constant. SLAM II provides an ALTER node by which resource availability may be so changed. Determination of the time period (T) during which VKES is being utilized by a mail type requires a user-written subroutine.

SLAM II provides an EVENT node as a mechanism for triggering the use of user-written FORTRAN subroutines. In the modification of the basic model, the arrival at VKES of the first entity, identified by an attribute, ATRIB(1), of each mail type initiates a call to subroutine EVENT. The procedure for coding of the subroutine called from the SLAM II network is identical to any FORTRAN subroutine.

The required user-written subroutine calculates the time period of VKES utilization (T), for each entity type, as the difference between the arrival time of the first and departure time of the last entity and the VKES. Note that the average resource utilization for that time period is not calculated directly in the subroutine. The user-written subroutine accomplishes this task by using the following logical sequence:

1. The value of attribute 1 is passed to the subroutine to identify the mail type.

2. The initial time of VKES utilization ITIME(ATRIB (1)) is assigned the value of system time (TNOW).

3. When the last entity of the batch is processed, as determined by entity count and batch size, ITIME is subtracted from TNOW to give the time period of VKES utilization, T1, T2, or T3 as appropriate.

4. Values for T are returned to the main program for inclusion in the output report.

Calculation of the unbiased statistics may now be accomplished. The area of A1 is equal to the product of RRAVG(1) and total simulation time. That area, A1, divided by T1 yields the time integrated average VKES utilization for mail type 1. Similarly, values for mail types 2 and 3 may be determined.

It should be noted that this logic adds complexity to the already involved network model, further obscuring the relationship of its nodes and activities to the functional components of the real system.

7. CONCLUSIONS

This paper shows how the logic of a simulation model is significantly modified in order to produce unbiased or undistorted statistics about the continuous mail processing system. The development of the initial model is straightforward in nature. However, its direct implementation produces statistics that are representative of the behavior of the simulated system mainly because of the interaction between the different types of mail and also because of the great variability in the processing of different mailpieces. The modifications introduced to remove the bias in collecting the data have rendered a reasonably straightforward model into a rather complex one. Additionally, the execution speed of both the SIMNET and SLAM II models is adversely affected with the introduction of the modifications. The present application is perhaps one of the very few cases where the model is modified in a serious manner to avoid distorting its output results.

REFERENCES

Pritsker, A. Alan, Introduction to Simulation and SLAM II, Halsted Press, Wiley, New York, 1986.

Taha, Hamdy A., Simulation Modeling and SIMNET, Prentice-Hall, Englewood Cliffs, N. J., 1987.

United States Postal Service, ZIP + 4 Business Plan, Publication 126, January, 1986.

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