INS: INTEGRATED NETWORK SIMULATOR

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INS is a Fortran based network simulation package. INS incorporates many of the concepts and features of the GERT simulation packages [1,2], including:
a) a network modelling philosophy and framework,
b) no programming requirements,
c) free form input, and
d) extensive input and execution diagnostics.

INS also provides the user many of the modelling capabilities of GPSS [3,4]. These capabilities include:
a) distinguishing between transactions (entities, jobs) of different types,
b) creating sets of logically related transactions (transaction sets [called assembly sets in GPSS]),
c) modelling complex processing dependencies among transactions within a transaction set, and
d) modelling preemption relationships among system activities (preempt, regular, and filler activities).

In addition, INS provides a user powerful capabilities for modelling the organizational and operational characteristics of multi-activity multi-resource service systems where typically:
a) activities may have multiple resource requirements, and
b) each resource may perform any number of activities in the system.

From the standpoint of a transaction these capabilities include selecting each resource required to perform an activity based on either:
a) no prior processing information, or
b) prior processing information related to any transaction in the same transaction set.

From the standpoint of a resource these capabilities include:
a) modelling sequences of activities performed on one or more transactions in a transaction set,
b) modelling an explicit decision algorithm used by a resource in selecting an activity sequence to initiate, and
c) specifying the arrival and departure characteristics of a resource.

This paper presents an introduction to the basic concepts, symbolism, terminology, and features of INS. Prior to the "general, abstract" overview, a description and conceptual model of a relatively complex system (an outpatient clinic) that can be modelled in a straightforward fashion using INS is provided in the next section. In section three we present the "formal" overview of INS, drawing upon the outpatient clinic example to lend substance to some of the concepts and terminology. In the fourth section we attempt to clarify and integrate most of the concepts, symbolism, terminology, and features of INS by presenting and describing in detail an INS model of the outpatient clinic characterized in section two. Finally, the last section discusses the current status of INS, and future developments.

AN OUTPATIENT CLINIC EXAMPLE

INS evolved in a health care environment as a result of a need to develop a simulation programming language that could be used to faithfully model the complex organizational and operational characteristics of outpatient clinics. These characteristics included:
a) a network structure of the care process administered to a patient,
b) multi-patient type processing,
c) interacting direct and indirect care processes,
d) discrete resource constraints (clinic staff, physical facilities, equipment)
e) multi-task (activity) capabilities of system resources
f) resource substitutability in the performance of different activities, and
g) complex decision algorithms used by each member of the clinic staff in selecting activities to perform.

In the context of an outpatient clinic system, INS has been used to predict the effects of:
1) different patient scheduling systems,
2) random arrivals of patients,
3) different patient loads and case mixes,
4) varying resource levels - including staffing and physical facilities,
5) different staff arrival and departure patterns,
6) alternative staff compositions and task (activity) delegation policies,
7) varying system (patient processing) structure,
8) varying service time parameters for activities, and
9) various combinations of the above,

on the operational performance of a clinic [5].

Drawing upon this experience in ambulatory care, we consider in this section an example of a "simplified" (less detailed) outpatient clinic system. The example will later serve to illustrate the basic modelling concepts and features of INS. A conceptual model of the organizational and operational characteristics of the clinic is depicted in figure 1 and tables 1-1 through 1-3, and should be referred to in the following discussion. The bold line circles and squares represent direct patient care delays and activities, respectively (a direct patient care activity is one performed on the patient). The broken line circles and squares identify indirect care delays and activities (activities performed on entities related to the patient). Finally, the thin line squares in the tables represent activities not depicted on the figure.

Clinic Resources

The outpatient clinic resource pool is listed in table 1-1 accompanying figure 1. The resources include ten staff members, six exam rooms, one triage desk, and one Coulter-S machine. These discrete resources are identified because of the fact that their scarcity can cause delays in the process of care delivery in the clinic.

Structure and Content of the Care Process

The clinic provides care to two types of patients: scheduled and walk-in. Upon arrival at the clinic a patient is checked in by the clerk. A delay occurs if the clerk is not available. On the other hand if the patient is a walk-in patient, he/she must be triaged by a Registered Nurse (RN) at the triage desk (triaging is a name given to the task of identifying the health care needs of a patient). A delay occurs if either or both the RN and the triage desk are not available (e.g. the second RN might be available, but the first RN is currently triaging another patient at the triage desk). In both the cases of a scheduled and walk-in patient, the check-in/triage activity generates paperwork (forms) to be completed by the clerk in his/her spare time (note the forms are not required to be completed before the patient leaves). Moreover, the medical record of a walk-in patient must be obtained before the subsequent exam.

After check-in/triage the patient is placed in an exam room by an RN or Licensed Practical Nurse (LPN), with the LPN preferentially performing the activity, if available. Scheduled patients utilize only scheduled exam rooms. Walk-in patients are preferentially placed in the

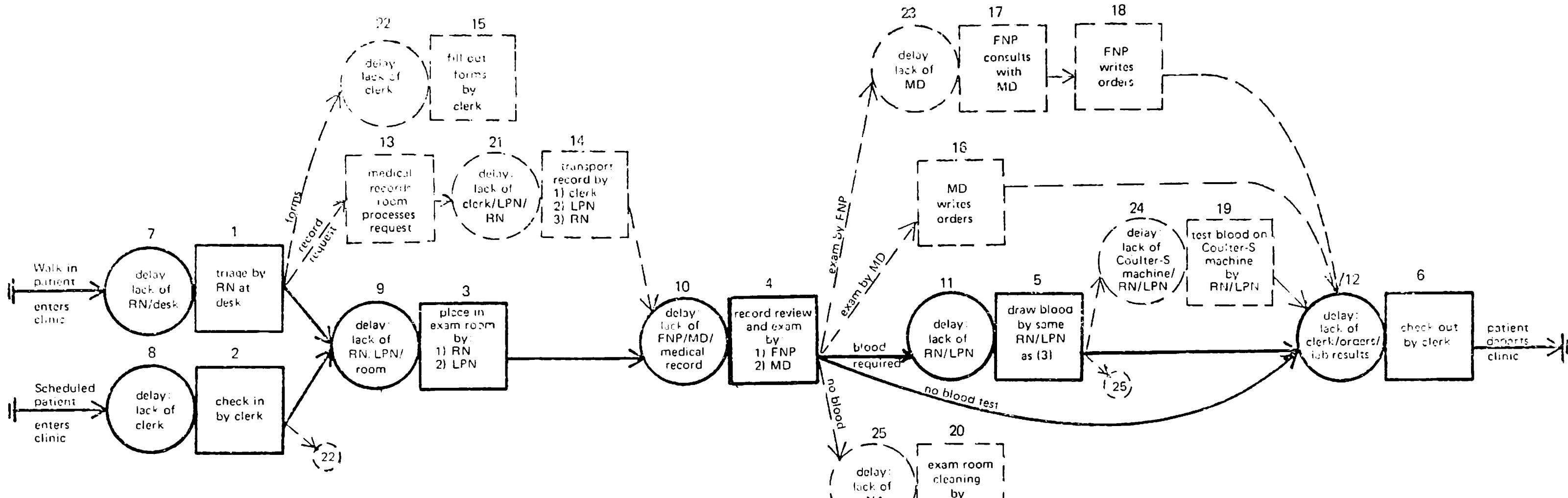


FIGURE 1 CONCEPTUAL MODEL: OUTPATIENT CLINIC EXAMPLE

TABLE 1-1 CLINIC RESOURCES

Resource Type (classification)	Resource Level
MD	2
FNP	3
RN	2
LPN	1
NA	1
Clerk	1
Scheduled Exam Room	5
Walk In Exam Room	1
Triage Desk	1
Coulter-S Machine	1

TABLE 1-2 RESOURCE ACTIVITY PROFILES

MD ACTIVITY PROFILE
- 1 record review and exam
- 16 write orders
- 17 consult
- 26 visit emergency room
- 28 lunch break

FNP ACTIVITY PROFILE
- 4 record review and exam
- 17 consult
- 18 write orders
- 28 lunch break

RN ACTIVITY PROFILE
- 1 triage
- 3 place in exam room
- 5 draw blood
- 19 test blood
- 14 transport medical record
- 28 lunch break

LPN ACTIVITY PROFILE
- 3 place in exam room
- 5 draw blood
- 19 test blood
- 14 transport medical record
- 28 lunch break

NA ACTIVITY PROFILE
- 20 exam room cleaning
- 28 lunch break

CLERK ACTIVITY PROFILE
- 2 check in
- 6 check out
- 14 transport medical record
- 15 fill out forms
- 27 answer phone
- 28 lunch break

SCHEDULED AND WALK IN EXAM ROOM ACTIVITY PROFILE
- 3 place in exam room
- 4 record review and exam
- 5 draw blood
- 20 exam room cleaning

TRIAGE DESK ACTIVITY PROFILE
- 1 triage

COULTER-S MACHINE ACTIVITY PROFILE
- 19 test blood

TABLE 1-3 RESOURCE ACTIVITY SELECTION ALGORITHMS

MD ACTIVITY SELECTION ALGORITHM — preferred order
- 17 consult
- 4 record review and exam
- 28 lunch break

FNP ACTIVITY SELECTION ALGORITHM — preferred order
- 4 record review and exam
- 28 lunch break

RN ACTIVITY SELECTION ALGORITHM — preferred order
- 5 draw blood
- 3.1 place in exam room: scheduled patient
- 3.2 place in exam room walk in patient
- 1 triage
- 14 transport medical record
- 28 lunch break

LPN ACTIVITY SELECTION ALGORITHM — preferred order
- 5 draw blood
- 3.2 place in exam room: walk in patient
- 3.1 place in exam room: scheduled patient
- 14 transport medical record
- 28 lunch break

NA ACTIVITY SELECTION ALGORITHM — preferred order
- 20 exam room cleaning
- 28 lunch break

CLERK ACTIVITY SELECTION ALGORITHM — preferred order
- 2 check in
- 6 check out
- 14 transport medical record
- 26 lunch break
- 15 fill out forms

SCHEDULED EXAM ROOM ACTIVITY SELECTION ALGORITHM — preferred order
- 3.1 place in exam room: scheduled patient
- 3.2 place in exam room: walk in patient

WALK IN EXAM ROOM ACTIVITY SELECTION ALGORITHM — preferred order
- 3.2 place in exam room: walk in patient

TRIAGE DESK ACTIVITY SELECTION ALGORITHM — preferred order
- 1 triage

COULTER-S MACHINE ACTIVITY SELECTION ALGORITHM — preferred order
- 19 test blood

(one) exam room assigned to walk-ins. However, if the room is not available, an available scheduled exam room may be used. If either a) the LPN or an RN, or b) an exam room, or both are not available, the patient waits.

Once in the exam room, the patient's record will ultimately be reviewed, and an exam will be performed. A Family Nurse Practitioner (FNP) preferentially performs the activity. If no FNP is available, then an available MD may perform the activity. If neither an FNP/MD is available, the patient waits in the room. Moreover, the lack of the patient's record will cause a delay regardless of FNP/MD availability. In this case the available FNP/MD remains available to perform other activities. Patients waiting in exam rooms are seen on a priority basis, with scheduled patients given priority. Finally, the time required to perform the record review and exam activity is typically longer for a walk-in patient.

If the record review and exam is performed by an FNP, then following the activity a consultation with an MD will be required in the consultation area. If no MD is available, the FNP waits. Following the consultation, the FNP writes his/her orders. These are then passed to the clerk at the check-out counter. If an MD performed the record review and exam activity, he/she leaves the room to write orders. These are then given to the clerk.

The blood sample drawn by the RN/LPN must be tested on the Coulter-S machine, and the results must be obtained prior to the patient leaving the clinic. The RN/LPN who drew the blood will attempt to perform the activity immediately after drawing the sample. However, if the Coulter-S machine is being utilized (testing another blood sample), the RN/LPN will leave the sample and attempt to perform another activity elsewhere in the clinic, returning to perform the test as soon as possible. Once the test has been run, the results are passed to the clerk at the check-out counter.

Check-out is performed by the clerk, and requires that the following information be available before the patient is discharged: a) the MD's/FNP's orders, and b) the results of the blood test, if one was required. After checking out, the patient leaves the clinic.

Finally, three other aspects of the clinic operations not explicitly characterized in the conceptual model should be noted. First, the clinic holds two sessions during the day (morning and afternoon), and the clinic staff takes lunch breaks between the sessions. Second, the two MD's are intermittently preempted in their activities in the clinic by emergency room requirements. Third, incoming phone calls arrive randomly throughout the clinic sessions. The calls require that the clerk interrupt what he/she is doing to answer them. However, if the clerk is out of the clinic (transporting a medical record, or out to lunch), the calls are not answered.

Operating Characteristics of Clinic Resources

The set of all those activities identified in the clinic example that a given resource performs constitutes the resource's activity profile. Table 1-2 accompanying Figure 1 lists the activity profile for each clinic resource.

Consider the activity profile of the clerk. After performing an activity on a patient or informational item, the clerk typically has freedom to select the next activity he/she will perform; with the choice made using an activity selection algorithm. The activity selection algorithm for the clerk is characterized in Table 1-3. Those activities identified in the algorithm constitute choice activities for the clerk. First preference (or priority) goes to patients waiting to be checked in or checked out, and a choice among the patients is made on the basis of the patient who has waited the longest. The check-in/check-out activities are followed in preferred order by a) transport medical records, b) lunch break, and c) fill out forms. All activities, except filling out forms, are normally completed once started. However, they may be interrupted by an incoming phone call. The two activities that cannot be preempted are 1) picking up the medical record, and 2) taking a lunch break, since the clerk leaves the clinic for these activities. Filling out forms is to be done in the clerk's spare time (when there is nothing else to do), and may be interrupted by any other activity requirements.

Consider now the activity profile and activity selection algorithm for an FNP. Only two activities from the profile (record review and exam, lunch break) are identified in the selection algorithm. This characterization arises because of the fact that once "record review and exam" is initiated, the performance of the activities "FNP consults with MD" and "FNP writes orders" follows in a natural sequence. Thus, these latter activities constitute sequential rather than choice activities for the FNP.

Patient Arrival Process

The patient arrival process (not depicted in the conceptual model) is as follows: A modified block appointment system has been set up for scheduled patients. The patients are scheduled to arrive in groups of 4, at 30 minute intervals, from 8:00 A.M. until 11:00 A.M. for the morning session, and from 12:00 noon to 4:00 P.M. for the afternoon session.

Walk-in patients arrive randomly (according to a Poisson process) from the time the clinic opens (8:00 A.M.) and are accepted up to 11:00 A.M. for the morning session. In the afternoon walk-in patients are again accepted from noon until 4:00 P.M.

Clinic Staff Arrival, Lunch Break, and Departure Process

The MDs and FNPs arrive at 8:15 A.M. All other clinical staff member arrive when the clinic opens at 8:00 A.M.

Each staff member takes a lunch break as close to 11:30 A.M. as possible. MDs and FNPs take a 45 minute break. All other staff members are allotted 30 minutes.

Finally, staff members remain in the clinic after 4:00 P.M. only until they are no longer needed for patient processing.

INS CONCEPTS, SYMBOLISM, TERMINOLOGY, AND FEATURES

In this section we provide an overview of the basic modelling concepts, symbolism, terminology, and features of INS. The presentation is relatively abstract, reflecting the fact that INS is a general purpose network simulation package. However, in order to lend substance to some of the terminology and concepts, we will occasionally refer to the outpatient clinic example presented above. It will be left to the reader to deduce the applicability of INS to different types of systems.

INS Modelling Philosophy and Framework

The basic premise of INS is that a large body of systems can be conceptualized and graphically modelled as a set of networks. An INS network consists of nodes and branches. Each node in a network has a well defined functional role. Branches connect the nodes and structure the network. Entities flow through the networks and are processed on the nodes.

The ability to represent a system graphically as a set of networks provides an analyst with a number of benefits. These benefits include:
a) a bookkeeping and information synthesizing tool,
b) a means of identifying the data requirements for analyzing a system, and
c) a communications device and vehicle for participatory modelling.

INS Modelling Symbols

INS provides a user with nine powerful and flexible symbols with which to model a system. Each symbol has a particular modelling capability and set of parameters associated with it. By specifying values for the parameters on a particular symbol, the user characterizes a segment of reality he wishes to model. Integration of the symbols produces a network model of the system.

Eight different node symbols (node types) are provided by INS, and are displayed in table 2. The table also outlines each node type's functional role, and provides an abbreviated key to the parameters associated with each node. In particular, note that a resource(s) utilizing activity in INS is modelled using an activity node. Thus, INS is an activity-on-node network simulation package. Finally, those node types that qualify as departure nodes in INS are identified in the table by cross-hatching on the symbol. An entity resumes its flow through the network once processing of the entity on a departure node has been completed.

Table 3 outlines the functional role of the branch symbol. Multiple branches may be modelled on the output side of a departure node in INS. However, only one branch is taken by an entity when it departs the node. The method of selecting the branch to take is specified by the branching mode on the node. In addition, each branch on the output side of the departure node typically requires an above branch parameter set that specifies the criterion for selecting the branch. The structure of the above branch parameter set and the interpretation of the selection criterion is dependent on the branching mode. Table 4 lists the 12 branching modes currently available in INS, the above branch parameter set structure associated with each mode, and an interpretation of the selection criterion. Finally, table 5 identifies and characterizes the role of the three different types of below branch parameter sets that may optionally be specified below a branch in INS. Below branch parameter sets associate powerful modelling capabilities with a branch symbol.

Transactions

Entities flowing through INS networks are called transactions. A transaction typically represents a job or informational unit requiring one or more resource utilizing activities to be performed on it.

INS provides a modeller with two methods for generating transactions, and these two methods give rise to a two way transaction classification. A primary transaction is created and input into a network using a source node. Each primary transaction is logically independent (unrelated to) any other primary transaction. A derived transaction is spawned and input into a network when an existing transaction flows across a branch having a derived transaction parameter set specified below it (see table 5). A derived transaction is logically related to the transaction that spawned it. In the context of the outpatient clinic example, a primary transaction could represent a patient, while a derived transaction could represent a medical record request.

The ability to spawn derived transactions gives a modeller the capability to develop transaction sets; i.e., sets of logically related transactions. Each transaction set consists of one primary transaction and any number of derived transactions. In the clinic example transactions representing the patient, his/her medical record request, administrative form, and blood sample would be members of the same transaction set.

A transaction is represented in INS by a set of attributes that uniquely characterize the transaction and its current status in the system. This set of attributes is called a record. In addition, each transaction set has associated with it a shared attribute file. Entries are stored in the shared attribute file. Each entry consists of an attribute label (tagging ID) and an attribute value. The entries may be generated on:

a) assignment nodes,
b) activity nodes, or
c) below a branch, utilizing optional parameters in derived transaction parameter sets.

Any transaction in a transaction set is capable of generating entries in the set's shared attribute file. In turn, entries in the file may be used by any transaction in the set to:

a) route the transaction through its network,
b) rank the transaction in a queue (at a queue node),
c) block the start of an activity on the transaction,
d) identify the resource(s) to be utilized in processing the transaction at an activity node, and
e) selectively generate other entries in the shared attribute file.

Thus, the shared attribute file provides the key to modelling complex processing dependencies that typically exist among a set of logically related transactions.

Resources

A resource is the basic unit utilized in processing a transaction on an activity node. A resource typically represents a person, facility, or piece of equipment. In the outpatient clinic example clinic staff members, exam rooms, the triage desk, and the Coulter-S machine are all resources. Generally, a resource can only process one transaction at a time (batch processing capabilities are provided in INS, but will not be discussed here).

Resource Classification. Each resource in an INS model is identified by a resource number and classified by resource type. Both of these numerical values are user specified. While the resource number must be unique for each resource, the same resource type may be specified for any number of resources. Typically, classification of resources by type follows a natural institutional or professional classification scheme. Identifying resources both by number and type provides the modeller increased flexibility in specifying resource requirements on activity nodes.

Activity Node Profiles. A resource is associated with an activity in an INS model by being explicitly (resource number) or implicitly (resource type) identified on a resource symbol within a candidate resource group on an activity node. The set of all activity nodes that a resource is associated with constitutes the resource's activity node profile. Some of the activities in the activity node profile may be sequential in time order of performance - i.e., performed in sequence on one or more logically related transactions in a transaction set. Typically, no freedom of choice exists regarding the performance of these activities. However, for other activities in the profile a choice capability does exist. The parameter used to classify an activity in a resource's activity node profile as a "choice" or "sequential" activity is the resource selection mode on the activity node.

Queue Selection Trees. The decision algorithm used by a resource in selecting a choice activity to perform from its profile is user specified in INS through the use of one or more selector nodes to model a selection tree. Because INS allows the user to:

a) model multiple queues on the input side of an activity node, and
b) associate a resource symbol on an activity node with either one queue or all queues on its input side,

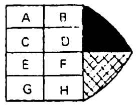
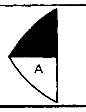
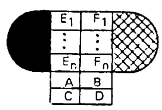
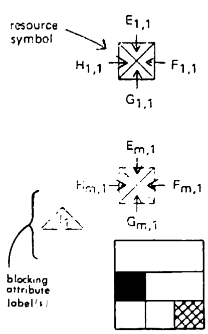
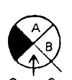
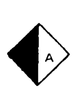
the selection tree of a resource is keyed to and incorporates queue node numbers rather than activity node numbers. Every queue node that:

a) is associated with a choice activity in a resource's activity node profile, and that
b) the resource may service,

is identified and incorporated into the resource's selection tree. Selector nodes and selection trees are not a part of the networks through which transactions flow.

Resource Arrival Process. In addition to modelling the operational characteristics of each resource in an INS system model, a user also models the arrival pattern of the

TABLE 2: INS NODE SYMBOLS KEY *

NODE TYPE	SYMBOL	FUNCTION	FIELD	DESCRIPTION
SOURCE		used to create primary transactions and schedule their arrival (represents a network entry point).	A	transaction type
			B	appointment time assignment: ARV: set appointment time = time of arrival ETA: set appointment time = expected time of arrival BIG: set appointment time = 1.0×10^6
			C	block size
			D	time to begin generating arrivals (first arrival occurs at this time)
			E	criterion for stopping arrival process: TIM: termination creation process when simulation time = time specified in field (F) NBR: terminate generation process when number of blocks = number specified in field (F)
			F	value associated with criterion in (E)
			G	interarrival time: A: constant interarrival time = A - A: interarrival time = value chosen from parameter set no. A
			H	early - late arrival time parameter set number
SINK		used to remove transactions from the system (represents a network exit point).	A	system realization counter specification: 0: do not include transaction realizations of sink node toward the number of sink node realizations required to realize the system N: include transaction realizations of sink node toward the number of sink node realizations required to realize the system
ASSIGNMENT		used to assign numerical attributes to transaction records, and entries to transaction set shared attribute files.	A	assignment mode: DET: deterministic assignment PRB: probabilistic assignment TTP: assignment conditional on transaction type ATL: assignment conditional on attribute label
			B	assignment type: TTP: assignment of transaction type to record ATV: assignment of entry (attribute label and attribute value) to shared attribute file
			C	for ATL assignment mode, the label of the attribute value to be tested against in the shared attribute file
			D	for ATV assignment type and PRB, TTP, or ATL assignment modes, the attribute label to be assigned to the entry in the shared attribute file.
			E_1	test/comparison value/label: assignment pair (1)
			F_1	value to be assigned: assignment pair (1)
			E_n	test/comparison value/label: assignment pair (n)
			F_n	value to be assigned: assignment pair (n)
ROUTING		used to route transactions through a network.		
ACTIVITY		used to model a resource(s) utilizing activity performed on transactions.	A	activity title (alphanumeric)
			B	activity type: P: preempt activity RNP: regular non-preemptable activity RP: regular preemptable activity F: filler activity
			C_1	resource selection mode: candidate resource group (1): 0: no resources required for this activity 1: select a resource on a priority basis 2: select the resource identified in the group whose number/(-) type is an attribute in the transaction's shared attribute file. 3: select the resource identified in the group that was utilized in the current realized activity 4: select the resource identified in the group that will transfer/(that attempted to transfer) to this activity node after completing an activity on another transaction from the same transaction set.
			C_m	resource selection mode: candidate resource group (m)
			D	attribute label for shared attribute file entry(s): 0 (blank): no shared attribute file entry(s) created N: create shared attribute file entry(s) having attribute label = N
			$E_{1,1}$	resource number/(-) resource type: resource candidate group (1), resource symbol (1)
			$F_{1,1}$	associated queue node: resource candidate group (1), resource symbol (1): 0 (blank): associate this symbol with all queues on input side of this activity node. N: associate this resource symbol with queue node (N) on input side of this activity node
			$G_{1,1}$	priority number (resource selection mode = 1)/attribute label (resource selection mode = 2): resource candidate group (1), resource symbol (1)
			$H_{1,1}$	activity time parameter set number/(-) attribute label: resource candidate group (1), resource symbol (1)
			$E_{m,1}$	resource number/(-) resource type: resource candidate group (m), resource symbol (1)
			I_1	first blocking attribute label specified for this activity node
QUEUE		used to model the queueing (delay) that occurs at an activity node due to resource(s) unavailability and/or process synchronization requirements among transactions in a transaction set. A queue node is always associated with an activity node	A	queue discipline: UL: unconditional, low value first UH: unconditional, high value first CL: conditional, low value first CH: conditional, high value first
			B	ranking attribute: -2: transactions in queue ranked by appointment time -1: transactions in queue ranked by transaction type 0: transactions ranked by arrival time at queue N: transactions in queue ranked by attribute value in shared attribute file having attribute label = N
			C_1	resource capture specification: resource candidate group (1): 0: do not capture the available resource if the associated activity cannot be started 1: capture the available resource only if no blocking attribute labels on the associated activity are currently active in the transaction's shared attribute file. 2: capture the available resource unconditionally
			C_m	resource capture specification: resource candidate group (m)
MARK		used to collect statistics on transaction flow times between two points in a network.	A	flow time statistics reference time specification
			B	mark time update specification
SELECTOR		used for modelling the decision algorithm used by a resource in selecting a waiting transaction on which to perform an activity. Selector nodes are not a part of the networks through which transactions flow.	A	selection mode PRF: selection in preferred order CYC: selection in cyclic order RAN: selection in random order LGQ: priority given to queue currently having the largest number of transactions in it SMQ: priority given to queue currently having the smallest number of transactions in it LGW: priority given to the queue for which the waiting time of the transaction that may utilize the resource is the longest STW: priority given to the queue for which the waiting time of the transaction that may utilize the resource is the shortest.

* Shaded area represents location of node number. Crosshatched area on a symbol identifies the branching mode location (see table 4)

TABLE 3: BRANCH SYMBOL KEY

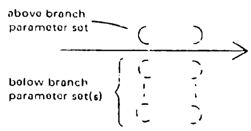
SYMBOL	FUNCTION	FIELD	DESCRIPTION
BRANCH  	a branch is used to connect two nodes in a network, and characterizes the precedence relationship between the nodes. the above branch parameter set specifies the selection criterion for choosing the branch. The selection criterion must be consistent with the branching mode specified on the branch's departure node. below branch parameter sets are used to: a) spawn derived transactions (derived transaction [DT] parameter set), b) synchronize the processing of two or more transactions in a transaction set (derived transaction [DT] and block release [BR] parameter sets), and c) model an activity sequence to be performed by one or more resources on two or more established transactions in the same transaction set (resource transfer [RT] parameter set)		see above branch and below branch parameter set keys

TABLE 4: BRANCHING MODE AND ABOVE BRANCH PARAMETER SET KEY

BRANCHING MODE ON DEPARTURE NODE	DESCRIPTION	ABOVE BRANCH PARAMETER SET STRUCTURE	BRANCH SELECTION CRITERION
DET	deterministic branching	None required	take this branch unconditionally
PRB	Probabilistic branching	(X)	take this branch with probability (X)
TTP	Branching conditional on transaction type	$\left(\begin{bmatrix}\text{EQ}\\\text{NE}\end{bmatrix}, \text{N}\right)$	take this branch if this transaction is $\begin{bmatrix}\text{equal to}\\\text{not equal to}\end{bmatrix}$ N
ATL	Branching conditional on assignment of attribute label to shared attribute file	$\left(\text{N}, \begin{bmatrix}\text{ASN}\\\text{NAS}\end{bmatrix}\right)$	take this branch if an attribute label = N $\begin{bmatrix}\text{was assigned}\\\text{was not assigned}\end{bmatrix}$ to this transaction's shared attribute file.
ATV	Branching conditional on attribute value in shared attribute file	$\left(\text{M}, \begin{bmatrix}\text{LT}\\\text{EQ}\\\text{GE}\end{bmatrix}, \text{N}\right)$	take this branch if the shared attribute file entry with attribute label = M has an attribute value $\begin{bmatrix}\text{less than}\\\text{equal to}\\\text{greater or equal to}\end{bmatrix}$ N.
IRE	Branching conditional on resource availability	$\left(\begin{bmatrix}\text{M}\\\text{-N}\end{bmatrix}, \begin{bmatrix}\text{IDL}\\\text{BSY}\\\text{OUT}\end{bmatrix}\right)$	for M: take this branch if resource number M $\begin{bmatrix}\text{is idle}\\\text{is busy}\\\text{has not arrived}\end{bmatrix}$ for -N: take this branch if $\begin{bmatrix}\text{any type N resource is idle}\\\text{all type N resources are busy}\\\text{no type N resource has arrived}\end{bmatrix}$
URE	Branching conditional on resource utilized in current realized activity	$\left(\begin{bmatrix}\text{M}\\\text{-N}\end{bmatrix}, \begin{bmatrix}\text{UTL}\\\text{NUT}\end{bmatrix}\right)$	take this branch if $\begin{bmatrix}\text{resource no. M}\\\text{a type N resource}\end{bmatrix}$ was $\begin{bmatrix}\text{utilized}\\\text{not utilized}\end{bmatrix}$ in current realized activity
ARE	Branching conditional on the assignment of a resource number (on an activity node) to the shared attribute file	$\left(\begin{bmatrix}\text{M}\\\text{-N}\end{bmatrix}, \begin{bmatrix}\text{ASN}\\\text{NAS}\end{bmatrix}, \text{I}\right)$	take this branch if $\begin{bmatrix}\text{resource no. M}\\\text{a type N resource}\end{bmatrix}$ was $\begin{bmatrix}\text{assigned}\\\text{not assigned}\end{bmatrix}$ on an activity node as an attribute value to the shared attribute file entry with attribute label = I
TIM	Branching conditional on current simulated time	$\left(\begin{bmatrix}\text{LT}\\\text{GE}\end{bmatrix}, \text{X}\right)$	take this branch if current simulated time is $\begin{bmatrix}\text{less than}\\\text{greater or equal to}\end{bmatrix}$ X.
LNQ	Branching conditional on current queue length	$\left(\text{M}, \begin{bmatrix}\text{LT}\\\text{GE}\end{bmatrix}, \text{N}\right)$	take this branch if queue M currently has $\begin{bmatrix}\text{less than}\\\text{greater or equal to}\end{bmatrix}$ N transactions in it.
SMQ	Take branch on output side whose destination queue node has the smallest number of transactions in it.	None required	
RAN	Branching at random	None required	

TABLE 5: BELOW BRANCH PARAMETER SET KEY

PARAMETER SET TYPE	PARAMETER SET STRUCTURE	FUNCTION	FIELD	DESCRIPTION
Derived Transaction	(DT, A, B, C)	used to spawn a derived transaction, and optionally generate shared attribute file entries to be used as blocks on activity nodes in order to synchronize the processing of transactions in a transaction set.	A B C	input (destination) node number of spawned transaction optional parameter. If specified, a shared attribute file entry is created with: a) attribute label = B, and b) attribute value = spawning transaction internal ID. Parameter B may then be specified as a blocking attribute label on activities in the network of the spawning transaction. optional parameter. If specified, a shared attribute file entry is created with: a) attribute label = C, and b) attribute value = spawned transaction internal ID. Parameter C may then be specified as a blocking attribute label on activities in the network of the spawned transaction.
Block Release	(BR, A)	used to synchronize the processing of transactions in a transaction set by removing a block on one or more activity nodes generated by processing a derived transaction parameter set.	A	blocking attribute label whose attribute value is to be set = 0.
Resource Transfer	(RT, A, B_1, B_2, ...B_{MXRQD})	used in conjunction with a resource selection mode = 4 on an activity node to model the performance of two activities performed sequentially by one or more resources on two existing transactions in the same transaction set.	A B_1 ⋮ B_{MXRQD}	number of activity node resource(s) to be transferred to resource transfer specification: resource candidate group (1) 0: do not transfer the resource from candidate group 1 used in the current realized activity 1: attempt to transfer the resource from candidate group (1) used in the current realized activity (repeat parameter B_1 for up to MXRQD resources utilized in the current realized activity)

system resources. This is accomplished by individually specifying a deterministic or probabilistic arrival time for each resource in an INS model.

Events in an INS Simulation

Three basic events "drive" an INS network simulation, and a general understanding of the processing logic executed by the INS simulation program at event times is an essential requirement for successful modelling using the language. The three basic events are depicted in table 6 below.

TABLE 6: BASIC EVENTS IN AN INS SIMULATION

Arrival (creation) Of Primary Transaction Event	Arrival Of Resource Event	End Of Activity Event
update status of transaction		update status of transaction
	update status of resource	update status of resource(s)

Arrival of Primary Transaction Event. When a primary transaction arrives (is created at a source node), the transaction departs the source node and flows through the network from node to node in zero simulated time until it achieves an updated status. An updated status is attained at:

a) a sink node (transaction destroyed [leaves system]),
b) a queue node (transaction delayed in the queue), or
c) an activity node (processing of transaction by resource(s) begins).

In the case of (b) or (c) the arrival of the transaction at a queue/activity node triggers the execution of the transaction initiated search for resources that are to be utilized in processing the transaction at the activity node. One resource from each resource candidate group on the activity node is utilized in processing the transaction. The search involves an independent examination of each resource candidate group, according to the resource selection mode for each group, to both:

a) identify the resource(s) specified in each group that are candidates for performing the activity on the transaction, and
b) determine the availability of the candidate(s).

The search terminates with the activity being initiated or the transaction filed in a queue. In either case the transaction has attained an updated status.

Arrival of Resource Event. When resource arrives, the resource initiated search for waiting transactions is carried out. In this case the resource's selection tree is used, and an attempt is made to assign the resource to a transaction waiting in a queue and start the associated activity. The search terminates with the resource assigned to a transaction or the resource entering the idle state. In either case the resource has achieved an updated status.

End of Activity Event. If the event is an end of an activity, the activity becomes the current realized activity for the system, and a two step status update is carried out. In step 1 the transaction departs the activity node and flows in zero simulated time from node to node in its network until it attains an updated status. In particular, in achieving an updated status at a queue/activity node, the transaction initiated search for resources is carried out. In step 2, any resources from the current realized activity that remain available for reassignment have their status updated. The resource initiated search for waiting transactions is carried out for each remaining resource, and results in the resources being assigned to waiting transactions or entering the idle state.

Time Advance. It must be emphasized that time advance in an INS simulation occurs only at the time of occurrence of any of the three basic events described above. The processing logic associated with updating the status of a transaction/resource is executed in zero simulated time.

Modelling Resource Requirements on Activity Nodes

In INS up to ten resources may be used in processing a transaction at an activity node. The alternative resources that may be utilized are identified in candidate resource groups on the node. Each candidate resource group consists of one or more resource symbols. In turn, each resource symbol identifies a particular resource (by resource number) or resource type that may meet the processing requirements of a transaction at the activity node. Thus, multiple resource requirements are modelled using multiple candidate resource groups.

The method used to identify/select a resource from a particular candidate group to perform the activity is specified by the resource selection mode for the group. A resource selection mode is individually and independently specified for each candidate group. The five possible selection modes are displayed in Table 7 below.

TABLE 7: CANDIDATE RESOURCE GROUP RESOURCE SELECTION MODES

Resource Selection Mode	Description
0	no resources required to perform the activity
1	select a resource on a priority basis
2	select the resource identified in the group whose number/(-) type is an attribute in the transaction's shared attribute file
3	select the resource identified in the group that was utilized in the current realized activity
4	select the resource identified in the group that will transfer/(that attempted to transfer) to this activity node after completing an activity on another transaction in the same transaction set.

The appropriate specification of resource selection modes on activity nodes is the key to modelling the operating characteristics of multi-activity, multi-resource systems using INS. The selection modes perform a dual function. First, they specify the methods to be used to identify/select the resources required to perform an activity in the process of executing the transaction initiated search for resources. Second, they identify the activities in a resource's activity node profile that qualify as choice activities. Those activity nodes having both:

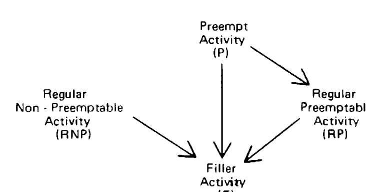
a) a resource selection mode = 1 or 2 for the candidate resource group that the resource is identified in, and
b) having queues on their input side,

qualify as choice activities for the resource. Those activity nodes having a resource selection mode = 3 or 4 specified for the candidate group the resource is identified in represent sequential activities for the resource.

Classifying Activities (Modelling Preemptive Relationships) in INS

Each activity in an INS model is user classified by type, and a specific preemption relationship exists among the different activity types. Figure 2 depicts the activity classification scheme in INS. The preemptive relationships that exist between the different activity types are identified in the table by directed arrows.

FIGURE 2: ACTIVITY TYPES AND PREEMPTIVE RELATIONSHIPS IN INS



A preempt activity (P) may be viewed as an activity requiring immediate attention (no waiting on the part of a transaction). As such, the resources required to perform the activity are preempted if necessary (unless currently performing another interrupt activity, a regular non-interruptable activity, or out of the system) and the activity is started immediately. If resource requirements for the activity cannot be filled, the transaction is removed from the system.

Regular activities may be viewed as activities that, once initiated, are performed to completion. However, regular preemptable (RP) activities may be preempted by interrupt activities.

Finally, filler activities may be viewed as activities performed in a resource's "spare time". This class of activities is preemptable by any other activity in the system except another filler activity.

Simultaneous Transaction Management Algorithm

The modelling capabilities associated with below branch parameter sets (e.g. - spawning derived transactions) requires that the INS simulation program have incorporated an explicit procedure for simultaneously (in zero simulated time) updating the status of more than one transaction is a transaction set. Called the simultaneous transaction management algorithm, this procedure achieves an updated status for each transaction in a well defined sequential manner. For example, if an existing transaction spawns a derived transaction, (by flowing across a branch having a derived transaction [DT] parameter set modelled below it) the simultaneous transaction management algorithm will attain an updated status for the derived transaction prior to achieving an updated status for the spawning transaction.

Using below branch parameter sets, the modeller can create far more complex simultaneous transaction management situations (e.g., a newly spawned derived transaction spawning other derived transactions prior to achieving an updated status, removing a block on the start of an activity for a transaction waiting in a queue, etc.). As such, knowledge of the way the simultaneous transaction management algorithm operates can be useful to the modeller in that he can effectively orchestrate (by appropriately modelling parameter sets below branches) the sequence in which the transactions achieve an updated status.

INS Input

Once a graphical model of the system to be analyzed is developed using the INS modelling symbols, the data contained on the graph is encoded on a set of data cards. The INS simulation program accepts the data and produces a simulation of the system. To facilitate the encoding process INS provides freeform input capabilities. Moreover, INS also provides extensive input and execution diagnostics that aid in debugging the network models a user creates.

INS Output

INS output currently consists of both standard and optional statistical information collected during the course of a simulation. Discrete statistics are optionally tabulated at any queue node (waiting times), activity node (activity times), mark node (flow times), and sink node (total flow times and total waiting times) in an INS model (as specified by the user). The statistics on any node may be collected in an aggregate fashion (no distinguishing between transaction types), or by transaction type, or both. Information is output that allows the user to develop confidence intervals for the mean of the performance measure using either:
a) individual observations of the random variable, or
b) multiple simulation runs of the system.
In addition, the extreme values (minimum and maximum) observed for:
a) the individual observations of the random variable, and
b) the mean of the random variable for each simulation run
are also output.

Time integrated statistics on both:
a) the average number of transactions at each queue node in an INS model, and
b) the average utilization of each system resource comprise a part of the standard statistical output of an INS simulation. Multiple simulation runs must be used to develop confidence intervals for the means of these measures. Other optional information that may be output includes:
a) statistics on the average number of transactions in a set of queues, and
b) utilization statistics by resource, by activity (matrix output) for each resource and activity in the model.

Finally, standard and optional statistics are generated by INS that are useful in estimating storage (core) requirements for running INS simulation models.

INS MODEL: OUTPATIENT CLINIC EXAMPLE

In this section we will attempt to illustrate and integrate many of the INS modelling concepts, symbols, and features presented above by examining an INS model of the outpatient clinic presented in the second section. The INS graphical model is depicted in figure 3. In the following discussion the reader should make use (as required) of the node and branch related keys presented in tables 2-5.

Clinic Resources

Pertinent information regarding the clinic resources is depicted in tabular form in the lower left hand corner of figure 3. Each resource is identified both by number and type. The primary selector node number in each resource's selection tree is also identified (the selection trees will be considered later). Finally, the arrival time of each clinic resource is tabulated. Except for the MDs and FNPs who arrive at 8:15 A.M. (495 time units), all clinic resources are available at the time the clinic opens.

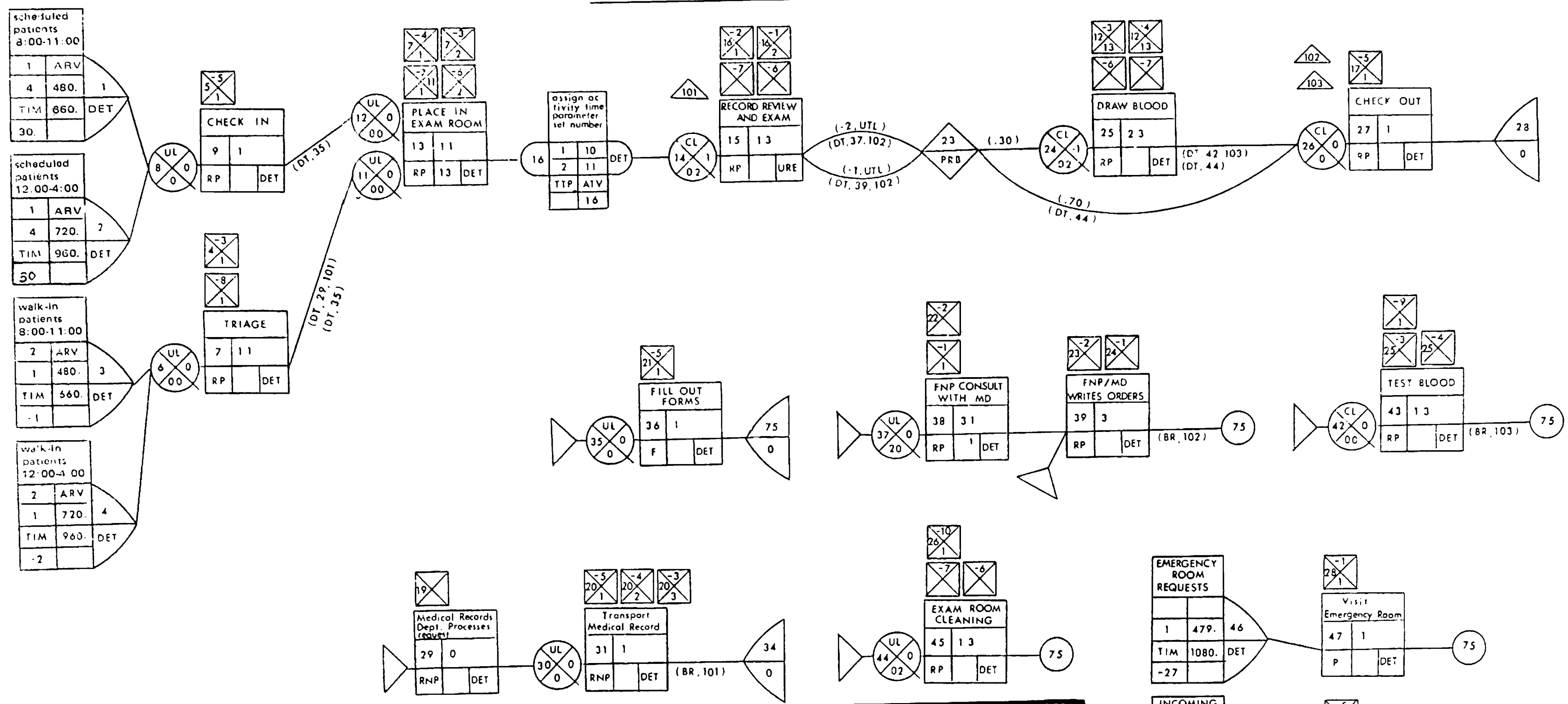
Patient Arrival Pattern

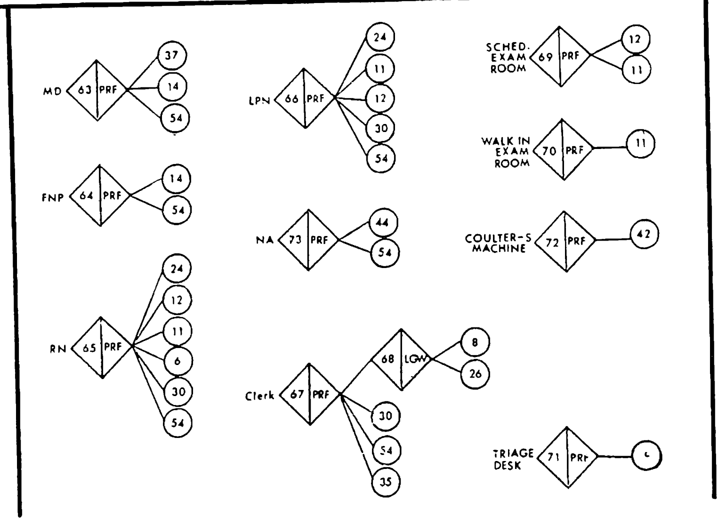
The patient arrival process is modelled using source nodes 1-4. Source node 1 creates scheduled patients (primary transactions), in blocks of 4, from 8:00 (480) to 11:00 (660), with a 30 minute interarrival time between blocks. Source node 3 creates individual arrivals of walk-in patients from 8:00 to 11:00, with interarrival times chosen from an interarrival time distribution characterized by parameter set no. 1 (-1 in field G). In a similar fashion source nodes 2 and 4 generate afternoon arrivals of patients. Note that scheduled patients (primary transactions) created at source nodes 1 and 2 are assigned a transaction type = 1 (field A), while walk-in patients are assigned a transaction type = 2.

Process of Care Delivery

Upon being created (arrival of primary transaction event) a scheduled patient departs the source node (deterministic [DET] branching node), and in zero simulated time flows to queue node 8. Since the destination node is a queue node the transaction initiated search for required resources needed to perform the associated "check-in" activity (activity node 9) commences. Only one resource is required to perform the activity (one candidate resource group consisting of 1 resource symbol). The resource selection mode has been set = 1, indicating that a resource is to be selected on a priority basis. Information on the resource symbol identifies any type 5 resource (-5 in upper triangle) as a candidate for selection (referring to the resource pool, the clerk is the only type 5 resource). The priority number for the resource symbol has been set = 1 (not required for only 1 resource symbol in the candidate group, but specified for completeness), and the activity time parameter set no. = 5. If the clerk is available (currently idle or filling out a form [filler activity 36]) he/she is seized by the patient (transaction) and the check-in activity commences. If the clerk is unavailable, the patient is delayed in the queue. The "UL" specified on the queue indicates that the queue discipline is "unconditional", with transactions ranked "low value first" on the ranking attribute (unconditional queueing in INS implies that transactions in the queue must be serviced in order-i.e.,first transaction

FIGURE 3: INS MODEL: OUTPATIENT CLINIC EXAMPLE





RESOURCE POOL

Resource Classification	Resource Number	Resource Type	Primary Selector Node Number	Arrival Time
MD	1	1	63	495
MD	2	1	63	495
FNP	3	2	64	495
FNP	4	2	64	495
FNP	5	2	64	495
RN	6	3	65	480
RN	7	3	65	480
LPN	8	4	66	480
Clerk	9	5	67	480
Sched. Exam Room	10	6	69	480
Sched. Exam Room	11	6	69	480
Sched. Exam Room	12	6	69	480
Sched. Exam Room	13	6	69	480
Sched. Exam Room	14	6	69	480
Walk In Exam Room	15	7	70	480
Triage Desk	16	8	71	480
Coulter - S Machine	17	9	72	480
NA	18	10	73	480

in the queue must be serviced before the second transaction, etc.). The ranking attribute = 0 (field B) indicates that transactions are ranked on the time of arrival at the queue. Finally, since only one resource is required to perform the activity, the resource capture code on the queue (field C_1) has no significance.

In a similar fashion, when a walk-in patient arrives, the patient flows in zero simulated time to queue 6, and the search for resources required to perform the triage activity is undertaken. Two resources are required to perform triage (2 candidate resource groups, with one resource symbol in each group), and a resource selection mode = 1 has been specified for each group. The lone resource symbol in candidate group 1 identifies any RN (-3 in upper triangle indicating any type 3 resources) as a candidate for selection. Similarly, the resource symbol in candidate group 2 identifies the triage desk (the only type 8 resource) as a selection candidate. If either or both resource requirements cannot be fulfilled, the patient is delayed in the queue. Since only one of the two resource requirements might be fulfilled (causing a delay), the resource capture codes on the queue node become significant. The two zeros specified on queue node 6 indicate that if a resource from candidate resource group (1) is available, or a resource from candidate group 2 is available, but the triage activity cannot be started, the resource should not be captured by the transaction delayed in the queue (i.e., the resource remains available).

Upon completion of the triage activity on a walk-in patient (end of activity event) the activity becomes the current realized activity for the system. A branch on the output side of the activity node is chosen (according to the branching mode on the node [DET]) and the patient flows in zero simulated time across the branch. However, prior to departing the node, any below branch parameter sets specified below the chosen branch are first processed. Two below branch parameter sets have been specified in the INS model. The first parameter set (DT, 29, 101) spawns a derived transaction (representing a medical record request) whose input (destination) node is node 29. The optional value 101 causes the INS simulation program to create an entry in the shared attribute file of this transaction set (the patient [spawning transaction] and record request [spawned transaction] are logically related members of the same transaction set) with:

a) an attribute label = 101, and
b) an attribute value = spawning transaction internal ID.

The significance of this state of affairs lies in the fact that the value 101 is also specified as a blocking attribute label in the network of the spawning transaction on the activity node "record review and exam", and acts as a block on the start of the activity, contingent on the patient's medical record being processed and transported back to the clinic.

Focus now on the derived transaction representing the medical record. Its destination or input node is activity node 29 (note that the triangular symbol [▷] identifies a network entry point for a derived transaction in an INS graphical model). The resource selection mode on the activity node = 0, implying that no resources are required to perform the activity. As such, the lone resource symbol is used only to identify the activity time parameter set number (19), and the activity is immediately started. Since this derived transaction attained an updated status, processing of the second below branch parameter set (DT, 35) is initiated. This parameter set spawns a derived transaction, representing an administrative form, whose input node is node 35. If the clerk is available (currently idle) the "fill out forms" activity is started. If not, the derived transaction is delayed at queue 35.

After updating the status of the second derived transaction, the walk-in patient, at activity node 7, departs the node and flows to queue node 11. At the queue the transaction initiated search for resources required to perform the "place in exam room" activity takes place. Two resources are required (two candidate groups, with two resources per group), and both resource selection modes = 1. Consider the first resource candidate group. The LPN (type 4 resource) and RNs (type 3 resources) are identified as candidates for selection, with the LPN given a priority = 1, and an RN a priority = 2. Note in particular, that if the LPN isn't available, a resource selection mode = 1 implies that the RN who performed the triage activity (current realized activity for the system) does not necessarily have to place the walk-in patient in the exam room. This raises an important modelling concept in INS: a transaction has access to, and may utilize a resource from the current realized activity only through specification of a resource selection mode = 3 for a candidate group on the succeeding activity node. Consider now the second candidate group. The two resource symbols identify the walk-in and scheduled exam rooms (type 7 and type 6 resources, respectively) as potential candidates for selection. Note however, that the walk-in exam room can only service queue node 11 (the associated queue node number in field $F_{2,1}$ on the resource symbol = 11), while scheduled exam rooms can service both queues ("blank" in field $F_{2,2}$). Moreover, the walk-in exam room has been assigned a priority = 1, while the scheduled exam room has a priority = 2. Thus, when the walk-in patient arrives at queue 11 the walk-in exam room will preferentially be chosen, if available; while for a scheduled patient arriving at queue 12, only a scheduled exam room is a candidate for use. Finally, if resource requirements cannot be fulfilled, the walk-in patient is delayed at queue 11.

Once the status of the walk-in patient has been updated, the status of the resources (RN and triage desk) from the current realized activity (triage) is updated. The RN may use her selection tree (see selector node 65) and in preferred (PRF) order (i.e. - starting at queue 24) attempt to associate herself with a waiting transaction at queue 24, 12, 11, 6, 30, or 54. In a similar fashion the triage desk uses its selection tree to attempt to reassign itself to another patient (transaction) waiting to be triaged.

After the "place in exam room" activity has been completed the patient will depart the node and flow to assignment node 16. However, the value (13) in the middle bottom box on the activity node indicates that prior to departure two entries in the patient's shared attribute file should be generated. Each entry has an attribute label = 13. The first entry has an attribute value = resource number of the resource from the first resource candidate group that processed the patient (LPN or RN), while the second entry has an attribute value = resource number of the resource from the second resource candidate group that processed the patient (exam room). The first shared attribute file entry can be utilized later to identify the LPN/RN who is to "draw blood" at activity 25.

Upon arriving at assignment node 16, a shared attribute file entry (ATV assignment type) with attribute label = 16 is generated. The assignment mode is conditional on transaction type (TTP). A scheduled patient is assigned an attribute value = 10, while a walk-in patient is assigned an attribute value = 11 (the attribute value will be used to represent the "record review and exam" activity time parameter set number).

Processing on the assignment node occurs in zero simulated time, so upon being assigned a shared attribute file entry the transaction departs the node and flows to queue 14. At the queue the search for the resources required for the record review and exam activity begins. A resource selection mode = 1 has been specified for candidate resource group 1. An FNP and MD (type 2 and type 1 resources) have been identified as candidates for selection, with an FNP given higher priority. The fourth parameter on both resource symbols = -16, indicating that the activity time parameter set number is the attribute value of any entry in the transaction's shared attribute file having an attribute label = 16.

A resource selection mode = 3 is specified for candidate resource group 2, indicating that a resource from the current realized activity (place in exam room) should be utilized. The information on the resource symbols identifies the exam room as the resource to be used.

Now regardless of the availability of the FNP or MD, a walk-in patient may be delayed due to the lack of his/her record. If the attribute value associated with shared attribute file entry 101 is greater than 0, the record is not available (the patient is blocked). The attribute value is reset = 0 when a transaction in the transaction set flows across a branch having a block release (BR) parameter set specified below it. This state of affairs is modelled in the network of the medical record. Thus, after the "transport medical record" activity is completed (signifying record availability), the branch on the output side of activity node 31 will be taken by the transaction, and the below branch parameter set (BR, 101) will be processed. The attribute value in shared attribute file entry 101 will be set = 0, and if the patient is currently delayed in queue 14, an attempt will be made to start the associated activity.

Consider now a patient delayed at queue 14. The resource capture specifications on the queue indicate that the resource from candidate group 2 (the exam room) is to be captured unconditionally. The ranking attribute = -1 indicates that the queue is ranked by transaction type. The "CL" on the queue indicates conditional queueing, low value first. Conditional queueing in INS implies that transactions in the queue do not have to be serviced in order. This specification recognizes the fact that the queue is a logical (rather than physical) queue. The queue models patients waiting for service in different exam rooms. In particular, if two walk-in patients are delayed in the queue for lack of a medical record (each waiting in a different exam room), but the record of the patient last placed in the exam room should arrive first, that patient should not be constrained to wait for the record of the other walk-in patient preceding him.

Finally, note that once the activity "place in exam room" is completed and the status of the patient updated at queue/activity node 14/15, only the LPN/RN utilized in activity 13 will require a status update (the exam room seized by the patient at queue/activity node 14/15).

Other Aspects of the Care Delivery Process

Rather than continuing to describe in detail the INS model of the care process, only selected aspects will be considered. First, note that a newly spawned derived transaction has access to, and may utilize the resources that performed the current realized activity on the spawning transaction. Thus, after "record review and exam" is completed by an MD, the lower branch will be taken on the output side of activity node 15 (URE branching, and a type 1 resource (MD) utilized). As such a derived transaction representing a "write orders" job is generated and input at activity node 39. The resource selection mode = 3 on the activity node indicates a resource from the current realized activity is to be selected. Since the "record review and exam" activity is the current realized activity, the MD will be utilized.

At activity node 25 ("draw blood") the resource selection mode for candidate resource group 1 has been specified = 2. This indicates that the resource from the candidate group is to be identified through an entry in the patient's (transaction's) shared attribute file. The value (13) on each resource symbol in the group indicates that the attribute value identifying the resource is contained in the shared attribute file entry with attribute label = 13. Recall that these entries were generated at activity node 13 ("place in exam room"). Thus, resource selection mode 2, in conjunction with the shared attribute file, allows the modeller to specify that two or more nonsequential activities should be performed by the same resource on one or more transactions in a transaction set.

Source nodes 46 and 47 are used to create primary transactions representing emergency room requests and incoming phone calls, respectively. Consider an emergency room request. Upon arrival the transaction departs the source node and flows to activity node 47. The activity is specified as a preempt activity ("P" on the node). Thus if both MDs are busy, one may have to be preempted. An examination of the activity profile of the MDs indicates that all the activities they perform - except lunch break - have been modelled as regular-preemptable (RP) activities. The activity "lunch break" has been modelled as a regular - nonpreemptable (RNP) activity. Thus, if the MDs have not arrived or are taking a lunch break at the time the emergency room request arrives, they cannot be preempted, and resource requirements for the activity cannot be fulfilled. In this case the transaction representing the request is destroyed. Thus, in INS, queue nodes are never modelled on the input side of preempt activities.

Finally, note that source node 61 and sink node 62 control the simulation running time. At time 1080 a primary transaction is created and flows to sink node 62. Parameter A on the sink node has been set = 1. When the transaction realizes the node (leaves the system) the number of realizations required to realize the system (stop the simulation) is decremented by (1). Thus, by specifying one sink node realization to realize the system, the simulation will stop at time 1080.

Queue Selection Trees

The queue selection trees for all the clinic resources are depicted in the lower middle of figure 3. Five aspects of the trees should be noted. First, the trees are not a part of the networks through which the transactions flow.

Second, each tree has one primary selector node - the node at which the selection tree is entered. For all selection trees but the clerk's, the primary selector node is the only selector node. The ability to model multiple selector nodes in queue selection trees greatly enhances the user's ability to model complex selection processes using INS.

The third aspect to note is that the same queue selection tree may be referenced by any number of resources. Thus, both MDs use the selection tree identified by primary selector node 63, all FNPs use the tree identified by primary selector node 64, etc.

Fourth, note that each queue node identified in the selection tree of a resource is a queue on the input side of an activity node having a resource selection mode = 1 or 2 for the candidate group the resource is identified in. Thus, queue node 14 is not in the selection tree of an exam room because the resource selection mode for the second candidate group on activity node 15 is equal to 3.

Finally, note that keying the selection tree to queue node numbers rather than activity node numbers enhances the types of processing priorities that may be modelled for a resource. This is best exemplified by the selection tree of the RN, where a priority relationship between two queues on the input side of the same activity node (queues 11 and 12 on the input side of the "place in exam room activity") has been modelled. Thus, the RN preferentially places a scheduled patient in an exam room.

CURRENT STATUS AND FUTURE DEVELOPMENTS

INS is currently operational on the CDC 6600 at Indiana University. A user's manual is being developed, and the projected completion date for the documentation is June 1.

Future program developments include appropriate interfaces for user written subroutines (perhaps a node equivalent to the "help block" in GPSS, a user specified branching mode, a user specified resource selection mode, etc.), and extended output capabilities. Other developments will be keyed to user requests.

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