每題25分

Ph.D. Entrance Exam. (88.06.04)

(1) (a) State the basic kinematics assumptions of the Euler's beam theory.

(b) Derive the relationships between the applied external loads $q(x)$ and the bending moment $M(x)$ by the Newton's equilibrium law.

(c) Consider an Euler's beam with the clamp edge on the left-hand side and a spring support on the right-hand side as shown in the Figure below. Specify the boundary conditions for the spring support.

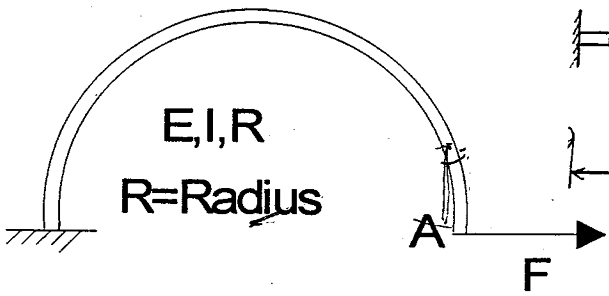


Fig.2

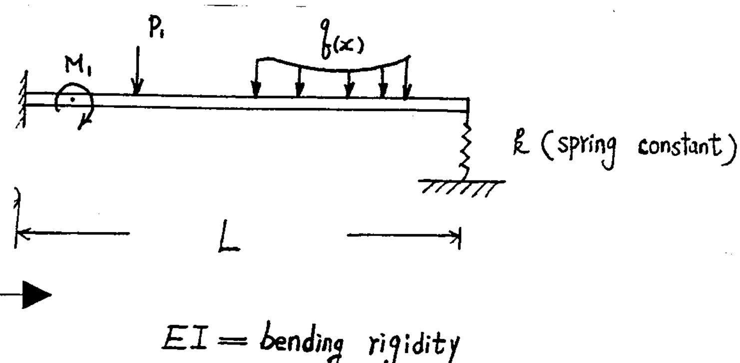


Fig. 1 problem 1

(2) A half circular beam is fixed at one end and free at the other end (point A). A force F is applied at point A. Find the horizontal deflection at point A for only considering the moment effect.

(3) Find the beam moments at points A and C in Fig.3.

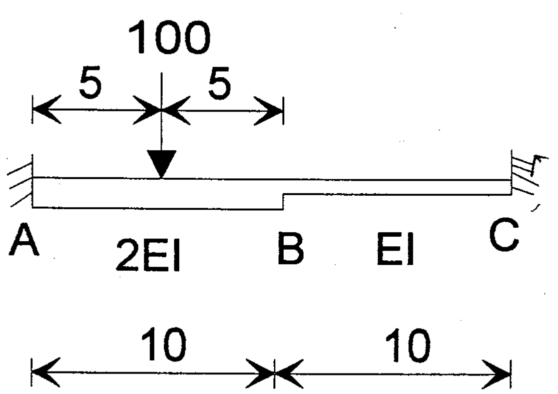


Fig.3

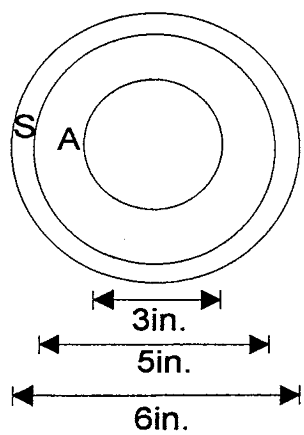


Fig.4

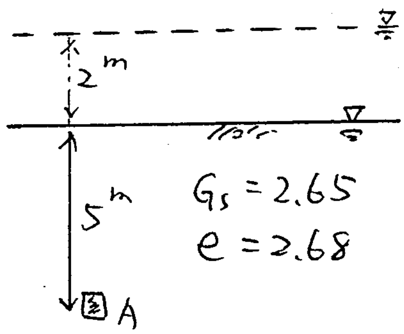
(4) A steel tub S is shrink-fitted over an aluminum tube A to form a composite shaft with diameters 3 in., 5 in. and 6 in. (see Fig.4). The allowable shear stresses in the steel and aluminum are τ_s=9 ksi and τ_a=4 ksi, respectively. Determine the allowable torque T_{allow} that may be applied to the shaft, assuming G_s=11600 ksi and G_a=4000 ksi.

博士班入學考題

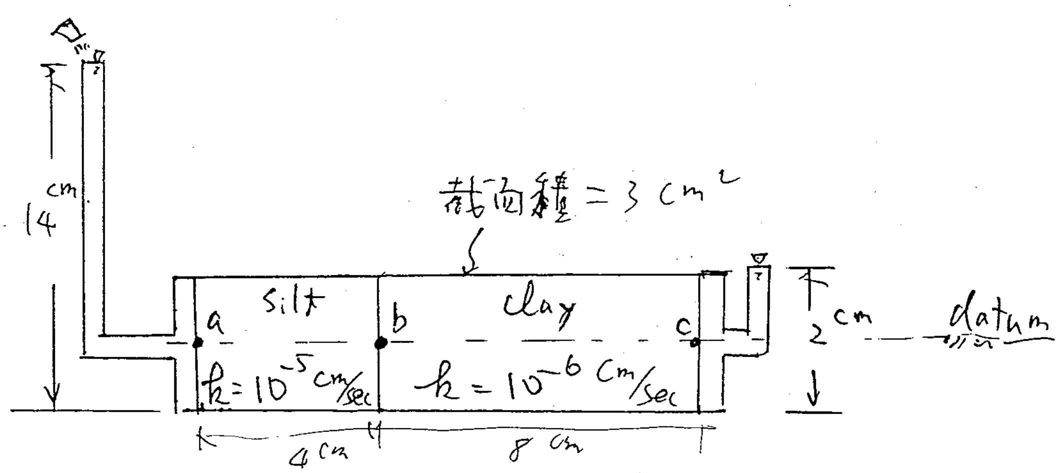
一. (a) 何謂 RMR(Rock Mass Rating)？ 其考慮的因素有那些？ 並請說明其原因。(10%)

(b) 請由作用於岩層之主應力關係說明不同斷層形成之原因及現象。(10%)

二.如右圖所示之砂土層，地下水位位於地表處，砂土之比重爲 2.65，孔隙比 e = 0.68，其有效內彎擦角$\phi' = 30°$ ，(a) 試就各種可能應用狀況下，解析地表下 5m 處，之有效剪力強度爲多少 kPa？ (b) 又若水位上升至地表上 2m 處時，其有效剪力強度應如何改變？(各 10%)



三. 如下圖所示，水流經兩種不同之土壤，試求(a). a，b，c 三點之總水頭，壓力水頭及位置水頭，(4%) (b) 其水平向之相當滲透係數？(4%) (c) 計算流經此管之滲流量，(4%) (d) 試繪水流經此兩個土層之流網。(Note：繪流網時，網格之垂直向之距離以 1 公分計) (4%) (e) 計算流經各土壤之滲流壓力？(4%)

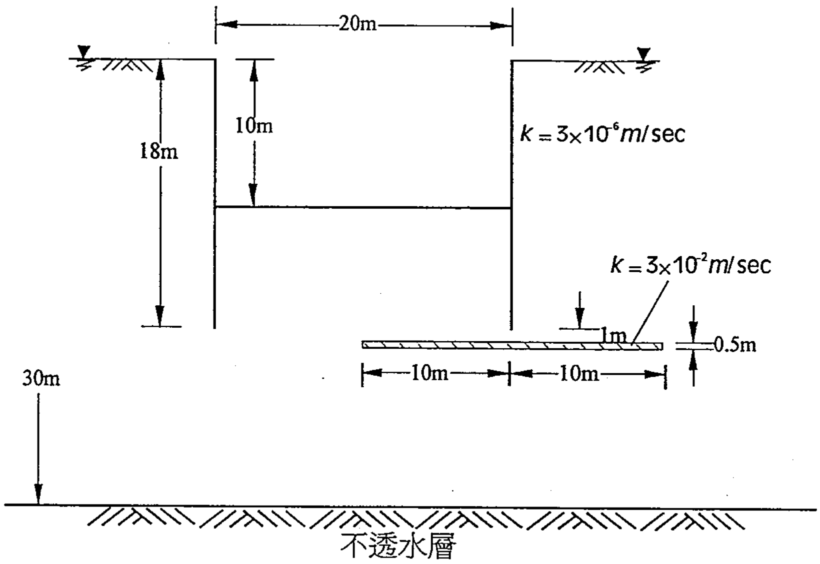


四. 對於一設有內支撐系統之版樁之支撐荷重設計，吾人可應用 Peck's 之經驗土壓力分佈圖，以決定主動土壓力 P_a 之數值，Peck's 將土壤區分爲砂土(sand)、軟弱至中等堅實粘土(soft to medium clay)及堅實粘土(stiff clay)三類，試問

(a) 應用 Peck's 之經驗土壓力計算式時，如何區別土壤爲軟弱至中等堅實粘土(soft to medium clay)抑或堅實粘土(stiff clay)？(10%)

(b) 於支撐側向荷重設計時，吾人假設除最上端及最下端之支撐外，其餘支撐點皆爲鉸接(hinged)，對於實爲連續之版樁，逕以鉸接處理，其理由安在？(10%)

五. 長條型開挖寬度 20m，深 10m。鋼版樁深入 18m 土層厚 30m，滲透係數 $k = 3\times10^{-6} m/sec$。一側版樁下 1m 處存在一極透水薄層寬 20m 厚 0.5m，$k = 3\times10^{-2} m/sec$。當地下水位於地表繪流線繪圖，估計開挖面單位長之出水量。(20%)



八十八學年度成功大學土木工程系博士班丙組入學考試

運輸工程試題

道路工程部分

1. 剛性路面理論分析通常分為哪幾種載重位置 ？(10%) 通常何種載重位置會產生面版最大拉應力？(10%) 通常何種載重位置會產生最大向下垂直變位？(10%) 如果以彈性基礎分析剛性路面，會產生什麼困擾？(10%)

2. 請列舉常見的柔性路面破壞，並說明可能之成因 (30%)

3. 請簡單說明 FWD、Road Rater、彭科曼樑之差異，並比較優缺點 (30%)

八十八學年度成功大學土木工程系博士班丙組入學考試

運輸工程試題

路面材料　(簡答題，每題２０分)

１ 現行瀝青規範如何限制瀝青之溫感性(Temperature Susceptibility)?

2　瀝青規範中之不同試驗，其中不同之試驗溫度所代表的實際意義爲何？

3　SHRP 之瀝青規範中，如何選用適當等級之瀝青？

4　夯壓程度對配合設計之決定最佳含油量有何影響？

5　SHRP 之瀝青規範如何確保鋪面成效？

八十八學年度土木工程研究所博士班丙組入學考試

運輸工程試題

三、交通工程

可用英文或中文作答。

Please read the attached paper and answer the following questions.

1. （30 分）What are the most important contributions of this paper?

2. （70 分）The authors pointed out the fact that line blockage is a major challenge to train dispatchers. Please explain, in your words, what line blockage is. How likely is line blockage going to happen on Taiwan's current railroad system?

(11)

A Structured Model for Rail Line Simulation and Optimization

E. R. PETERSEN and A. J. TAYLOR

Queen's University, Kingston, Ontario

A general purpose model of a railway line is presented. This model is based on an algebraic structure which describes the movement of trains over the line. This structure permits an arbitrary number of different trains with differing speeds and priorities to be dispatched over any line configuration including single or multiple tracks and sidings with restricted switching or cross-overs. Both optimization procedures and simulation models of the line can be implemented using this framework. The problem of line blockage at high traffic intensities is discussed, and conditions are given to ensure this does not occur. Computationally simple feasibility tests are presented together with a behaviorally based dispatching model. The model is implemented as a general purpose discrete event simulation model in which different dispatch goals or criteria can easily be included. Details of a validation example involving very high traffic intensity over a typical Canadian rail line are presented.

1. INTRODUCTION

The movement of trains over the roadway is central to all railroad operations. As such it has been the topic of considerable analysis over the past 20 years. The objective of these analyses has been (1) to evaluate train performance and line capabilities, (2) to evaluate different track facilities, or (3) to evaluate dispatching rules and procedures. These models of rail lines can be classified into three categories: (1) analytic (descriptive), (2) simulation, and (3) optimization models.

The analytic models develop closed form or algebraic expressions for the transit times for each type of train as a function of the train operating characteristics and the track configuration. Typical of these models are those by PETERSEN,[14-16] ELBROND AND DACOSTA,[6] and ENGLISH.[7]

The simulation models have the advantage that greater detail can be

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included and that transient behavior can be studied. Several simulation models have been developed with the more notable ones being: SIMTRAC (Lach and Skelton[10]; Peat, Marwick and Mitchell[13]); Australian Single Track Simulator (Rudd and Storry[20]); CN Route Schedule (Dubé and Belshaw[5]); and the Burlington Northern Simulator (Kehr[9]). All have had considerable use and acceptance. From these models we note three major limitations that in varying degrees restrict their continued use. They are: (1) an inflexible structure, arising from a model design for a specific railway problem, (2) excessive data requirements to operate the model, and (3) a difficulty in handling high intensity traffic due to line blockage.

Optimization models have been directed at the problem of scheduling trains over a line to optimize some criterion (e.g., capacity, total delay, etc.). This work has provided valuable insights and are of theoretical interest but as yet has had little application. A very interesting analysis of two-way traffic on a single track line was developed by Frank[8]. Brettman,[1] Chernyavskii,[2,3] Otway and Salzborn,[12] and Muller[11] have worked on the decision problem of scheduling trains over a line. More effort is required to make these approaches operational.

This paper presents a state space description of the problem of moving trains over a line, followed by an algebraic description of the relationships that must hold for feasibility and safety considerations. This results in a general framework within which either a simulation model or an optimization program can be formulated. The problem of line blockage at high traffic intensities is discussed with conditions given to ensure this does not occur. Simple feasibility tests are developed. Finally a behaviorally based dispatch procedure is described algebraically.

The final section of this paper illustrates the simulation model based on the above structure. This model is conceptually general, very simple and has been implemented as a FORTRAN program consisting of approximately 1800 statements. (Other simulation models have required well in excess of 10,000 statements in higher level languages like SIMSCRIPT.) An example using this model for a high traffic density on a typical Canadian rail line is presented.

2. STRUCTURE OF THE MODEL

Suppose there are n trains to be dispatched over the line, separated into two disjoint subsets OB and IB, denoting the outbound and inbound trains, respectively. Each train i, $i = 1, \ldots, n$, has length l_i and free running speed s_i. Each is released for departure from its originating yard at time r_i with desired arrival time g_i at the destination yard. Each train is also assigned a priority p_i.

2.1. Track Configuration

We assume that the line is divided into M segments representing the stretch of track between adjacent switches. Thus each segment represents a section of track between sidings or switches, a siding, or the origin or destination yard. For example, a siding on a single track line is a short double-track segment between longer single-track segments. We arbitrarily number the segments $m = 1, 2, \ldots, M$ in the outbound direction, with $m = 1$ and $m = M$ representing the terminal yards. Segment m is d_m miles in length, and has u_m parallel tracks and has b_m signal blocks on each track. The maximum speed on track k of segment m is v_{mk}. Track numbering $k = 1, 2, \ldots$ within a segment is assumed in the order of decreasing maximum transit speed (so track 1 has the fewest speed restrictions). We define a connection matrix $KO(m, k_1, k_2) = 1$ if an outbound train can switch from track k_1 on segment m to track k_2 on segment $m + 1$ and 0 otherwise. Similarly, $KI(m, k_1, k_2) = 1$ if an inbound train can switch from track k_1 on segment m to track k_2 on segment $m - 1$, and 0 otherwise. These connection arrays permit the modeling of limitations on possible crossover switches or single-end power-switched sidings. In addition, we assume that trains stop at the signals a distance δ from the switch, and the minimum safe headway distance is h for all trains. If $b_m > 1$, then intermediate signals exist on segment m and a train can follow another if a minimum train separation is maintained.

During certain periods of time a track within a segment may be unavailable due to maintenance requirements or prescheduled activities. Define ψ as the set of track outages. Then for each $i \in \psi$, let mm_i, km_i, $z1_i$, and $z2_i$ denote the segment, the track and the start and end time of the unavailable period, respectively.

2.2. Timing of Events

Let t_{imk} be the time for train i to traverse segment m on track k when free-running (i.e., when not delayed by train interferences). This time depends on speed restrictions which may vary from one track to another on a segment, allowing us to explicitly model slow-speed turnouts, for example. Similarly, h_{imk} is the minimum headway time for train i traveling on track k of segment m. When a train transfers from one segment to the next, we define τ_1 as the time lost in the preceding segment and τ_2 as the time lost in the next segment due to accelerating or decelerating the train. (Time lost here refers to the difference between the time actually taken by the train excluding time stopped on the segment and the free-running time.) Let τ_t be the time it takes for the train to pass the end of the segment. Finally, we define τ_d as the maximum of the two quantities: (a) minimum separation time between trains using the same facility, and

(b) the switching and dispatch response time. The latter is the time required for the dispatcher to sense that a train has cleared the facility and to reset the switches to allow the next train to enter the facility (where facility here denotes a particular track in a segment).

2.3. Safety

Safety requirements dictate that only one train may occupy a facility at any instant. This means that as a train passes from one facility to the next, both facilities must be reserved for exclusive use by that train during the appropriate time interval to ensure that no collisions occur. Trains may then follow each other if suitable separation is maintained. Minimum separations between trains occupying facilities must be observed.

To model this safety requirement, whenever a train leaves a facility, we create an imaginary "phantom train" to occupy the old facility until it becomes available for use by other trains. At this latter time, the phantom train is annihilated. We separate these phantom trains into two sets, *PO* and *PI*, representing "outbound phantoms" (associated with outbound trains in set *OB*) and "inbound phantoms," respectively.

Tracks may be scheduled out of service for maintenance or other requirements. When this occurs, we generate a phantom train to occupy the track, and denote this set of trains as *PM*. This will permit the current occupants to exit from the segment but will let none enter during the reserved period.

The total set of trains in the model is thus

$$\eta = OB \cup IB \cup PO \cup PI \cup PM. \tag{1}$$

2.4. Model Logic

The state of the system is completely specified if we know the contents of each set in (1) together with the following parameters,

x_i = the time that train i will complete its current activity (annihilation in the case of phantom trains),
A_i = location (segment number) of train i,
B_i = track number occupied by train i, and
D_i = 1 if train i is stopped on its track, and 0 otherwise, for all $i \in \eta$.

Time is advanced in the model by the occurrence of discrete events corresponding to the completion of current activities by the various trains. If the completed activity is for a phantom train, the train is removed from the appropriate set *PO*, *PI* or *PM* and time advances to the next event. If the event corresponds to a train arrival at its destination yard, the train is removed from the appropriate set *OB* or *IB*. In all other cases, when an activity is completed the dispatch routine decides whether the train either (1) proceeds to a specific track on the next segment, or (2) is delayed on the current facility.

The state of the train is updated to reflect its new status and the time the new activity will be completed. Furthermore, if the train occupies a new facility, a phantom train is created to occupy the previous facility until it is available for use by another train. Time then advances to the next event.

3. ALGEBRAIC SPECIFICATION OF THE MODEL

IN THIS SECTION we specify the analytic relationships which characterize the model. The detailed algebraic relationships are included in the Appendix.

The model can be initiated with any desired initial conditions. However, we normally start with the set OB containing the outbound and IB the inbound trains we wish to dispatch over the line, with the sets PO, PI and PM empty. We set $x_i = r_i$, the release time for each train i, $B_i = 1$, $D_i = 1$ (each train is stopped in its originating yard), and

$$A_i = \begin{cases} 1, & \text{if} \quad i \in OB, \\ M, & \text{if} \quad i \in IB. \end{cases}$$

Having specified the initial conditions, we now follow through the steps in the model.

The first step is to determine the next event which occurs at time

$$x_l = \min_{i \in \eta} \{x_i\} \tag{2}$$

and involves train l. If this is a phantom train or if the train is at its destination, then it is eliminated using relation (A1) and the next event is selected.

We next decide if l should proceed. To do this, we first determine the set of tracks K which are available for l to move onto. Identifying this set considers the physical switching possibilities, the set of trains (real and phantom) occupying the next track section, any intermediate signal blocks, and any tracks in that section which may be already reserved for higher priority traffic (K_r). The algebra for constructing this set is described in the Appendix, (A3)–(A7).

Because a track is available does not mean that it is feasible to move a train onto it. One must ensure that such a move does not result in a situation where no trains on the line can move further unless some train (or trains) reverse. This is called a "line blockage," and has been a problem encountered by most simulation models reported, and is a major concern and source of embarrassment for a train dispatcher.

3.1. Line Blockage

Both the simulation and the optimization literature have tried to resolve this problem by searching for a feasible path in the tree of train interactions that are possible as a result of the proposed train move. This becomes an exceedingly complex and large tree which with current methods is impossible to fully search. Heuristic methods which limit this search are usually imposed. A common method is to limit the search to 1, 2 or 3 further moves. That is, if the current move is made, then can 1, 2 or 3 subsequent moves also be made. Clearly, as the horizon is extended, greater computational effort is required.

Elsewhere (PETERSEN AND TAYLOR[18]) we have developed necessary and sufficient conditions on the outbound and inbound *fleets* of trains to ensure against line blockage. A description of a weaker but computationally efficient and behaviorally verified sufficiency condition on each fleet follows.

To avoid the complexity of the tree of individual train movements, we need only consider the two fleets of trains; the inbound and outbound trains. We define two conditions or states that each fleet can be in. A fleet of trains is said to be *simple meetable* if the trains in the fleet could feasibly be moved onto facilities in such a way that trains in the opposing direction have a feasible path to their destination yard. This condition clearly depends on the location of all trains, both inbound and outbound, and the track configurations. If trains could not be moved so that the opposing fleet can pass by, we say the fleet is *not simple meetable.*

A train move will be permitted and the line will not block if the fleet in the trains' direction will remain simple meetable after the move. Note that this criterion does not require elaborate examination of the tree of possible train moves, but rather is a single measure associated with each fleet. Stronger but computationally more cumbersome tests can be generalized from the above simple procedure.[18]

The procedure used to test if a fleet is simple meetable is to establish whether or not a feasible redeployment of trains in the fleet allows oncoming trains a feasible path past the fleet. We define a measure which represents the number of trains that need to be redeployed to free up a reverse path. This measure is adjusted as we proceed down the line. It increases by the number of forward fleet trains encountered, and decreases by the number of track locations that these trains can be moved onto and still have a reverse path. The reverse path does not need to be open but may be occupied by trains in the reverse fleet as they can follow each other when meeting the forward fleet. This counting procedure continues until the measure is reduced to zero or the end of the line is reached, in which case the fleet is simple meetable. If the forward trains could not be moved to open a reverse path, then the fleet is not simple meetable.

We now have our feasibility conditions. Train l on track k of segment m can feasibly be dispatched on track $\hat{k} \in K$ if the forward fleet remains simple meetable. We define this set of feasible tracks as F.

3.2. Dispatch Routine

The dispatch routine decides which track train l should proceed on, or if it should be delayed on its current facility. This can be formulated as the following optimization problem. An algorithm is required to select the track k_{ij} and segment exit times x_{ij}, $i \in OB \cup IB$, $j = A_i, \cdots, M$, $i \in OB$; $j = A_i \cdots, 1$, $i \in IB$; so that an objective function $f(X_t \mid A, B, X)$ conditional on the current state given by the vectors A, B, and X is minimized subject to the feasibility conditions in the Appendix, where X_t is the vector of terminating times for each train. This formulation assumes that the objective is based on the overall performance of each train. The specific form, however, will depend on whether the railway's objective is to maximize service, minimize cost or some intermediate criterion. Only heuristic algorithms are available for solving this optimization problem in practice.

A behaviorally based dispatch procedure is used in the model presented. It is behaviorally based in the sense of CYERT AND MARCH,[4] in that attention is paid to a few easily measured objectives with limited search among the alternatives. It appears that dispatchers follow such procedures, paying attention to a very limited number of goals and only extending their search when forced to by feasibility considerations. For example, dispatchers will give preference to the train with the highest priority. If trains have equal priority then the first one to leave a facility will proceed. If a train falls considerably behind schedule, then its effective priority is increased to give it preference in completing its run. Such simple rules appear to work well in practice. The model is designed so that different dispatch rules can easily be tested.

The dispatch procedure begins by determining the available tracks in the next segment and resolves any conflict between trains competing for the use of these facilities. To determine the set of contenders for the facility, we first define the time train i will arrive at segment m if it is permitted to continue its trip without any further delays as $y_i(m)$. The contender set for facilities at segment m is defined as

$$\Phi(m, x_l, \Delta) = \{i \mid x_l \leq y_i(m) \leq x_l + \Delta\}, \quad (3)$$

where Δ is some suitable interval of time, typically chosen to be the time for train l to transit the next two segments.

All members of the contender set have a claim on the use of the segment, and these conflicting claims must be resolved by the dispatch routine. The choice made by the dispatcher will depend on the objective he is trying to achieve, whether that be to serve the highest priority trains first, reduce the total delays in the system, or to ensure that trains maintain a preset schedule. We define this operation as a selection function $i = c(\Phi, m)$ for $i \in \Phi$, which selects the "best" train from the contender set. As an example, if the dispatcher selects trains based first on priority and within a priority class in the order in which they exit from segment m if continued, then

$$c(\Phi, m) = i$$

where
$$y_i = \min_{j \in \Phi}\{y_j(m) + t_{jm1} + \alpha p_i\}, \quad (4)$$

and α is a large positive constant. In this structure, the selection function may be a simple set of practice based rules or an elaborate optimization routine.

We now can decide what action the candidate train l should take. Using the selection function the "best" train from the contender set is selected. If this is the candidate train, then we assign the train to the best (i.e., fastest or preferred) feasible track available. If the set of feasible tracks is empty, then the train is delayed on its current facility. If the train selected is not the candidate train, and if the selected train can feasibly move to a subset of the feasible tracks, then the best of these reachable tracks is added to the set of reserved tracks K_r, the selected train is deleted from the contender set Φ and the process is repeated. The algebra of this procedure is given in the Appendix by expression (A8).

Since $l \in \Phi$, this procedure will determine $\hat{k}$, the action train l should take. If the set of feasible tracks is empty, $\hat{k} = 0$ and train l is delayed on the current track; otherwise $\hat{k}$ is the track number train l proceeds onto in the following segment.

The state of the system is updated using expressions (A9) through (A12). The model then advances to the next event, with the above process repeated.

4. TRAIN TIMING

IN THIS MODEL, reference has been made to a number of timing relationships. For example, t_{imk} is the time for train i to traverse track k of segment m. Similar expressions are defined for the time lost during acceleration or deceleration. The degree of detail in the equations describing train motion and track characteristics will vary depending on the purpose to which the model is applied. That is, a detailed dispatching study may require a great deal of detail and accuracy in reported train moves. On the other hand global study of the general effects on traffic flows of changes in plant may be more suitably done with simplified representations of train and track. Since appropriate models are well known, we do not repeat them here. A simplified set of relationships is, however, reported in PETERSEN AND TAYLOR.[17]

5. MODEL IMPLEMENTATION

THE FORTRAN program for this model contains approximately 1800 lines of code and requires approximately 80K words of storage. It will currently simulate 2000 trains over 200 track segments with up to 4 parallel tracks in each segment, though these limits are merely a matter of appropriately dimensioning arrays. The data input permits easy interactive experimentation in varying track, train, or traffic parameters. Track descriptors include the number of track segments and parallel tracks per segment, track maximum speeds, signal block spacing, and crossover/switch connections. Trains are described by maximum speed, length, priority, and acceleration characteristics. Traffic data include the number of trains of each type and schedule information (train departures can be either random, deterministic, or deterministic with a random variation around departure time).

The output from the simulator consists of several tables of summary data, including ones that describe the average performance of each train type and the cumulative delay at each segment along the line. Also available is a time-distance chart (string diagram) which for a one-day simulation is shown in Figure 1.

To validate the model, a 104-mile test line was considered with alternating single and double track and varying single block length. Fifty-one trains per day were dispatched over this line with 3 priority levels (passenger, express freight, and way freight) in each direction. Trains were dispatched according to a random normal deviation around equispaced departure intervals in 5 categories outbound and 6 inbound.

The timing calculations were simplified representations incorporating a uniform acceleration to train or track maximum speeds for each train category, and a constant headway distance. The selection logic employed was myopic, in that the highest priority train always took precedence in meets and overtakes, and otherwise a first come, first served logic applied to equal priority trains.

The testline was simulated for 30 days, for which the delay per train had a mean of 55.8 minutes with a standard deviation of 42.1 minutes. This compared well with a benchmark SIMSCRIPT simulation of the same line, which yielded a mean delay of 52.1 minutes with a standard

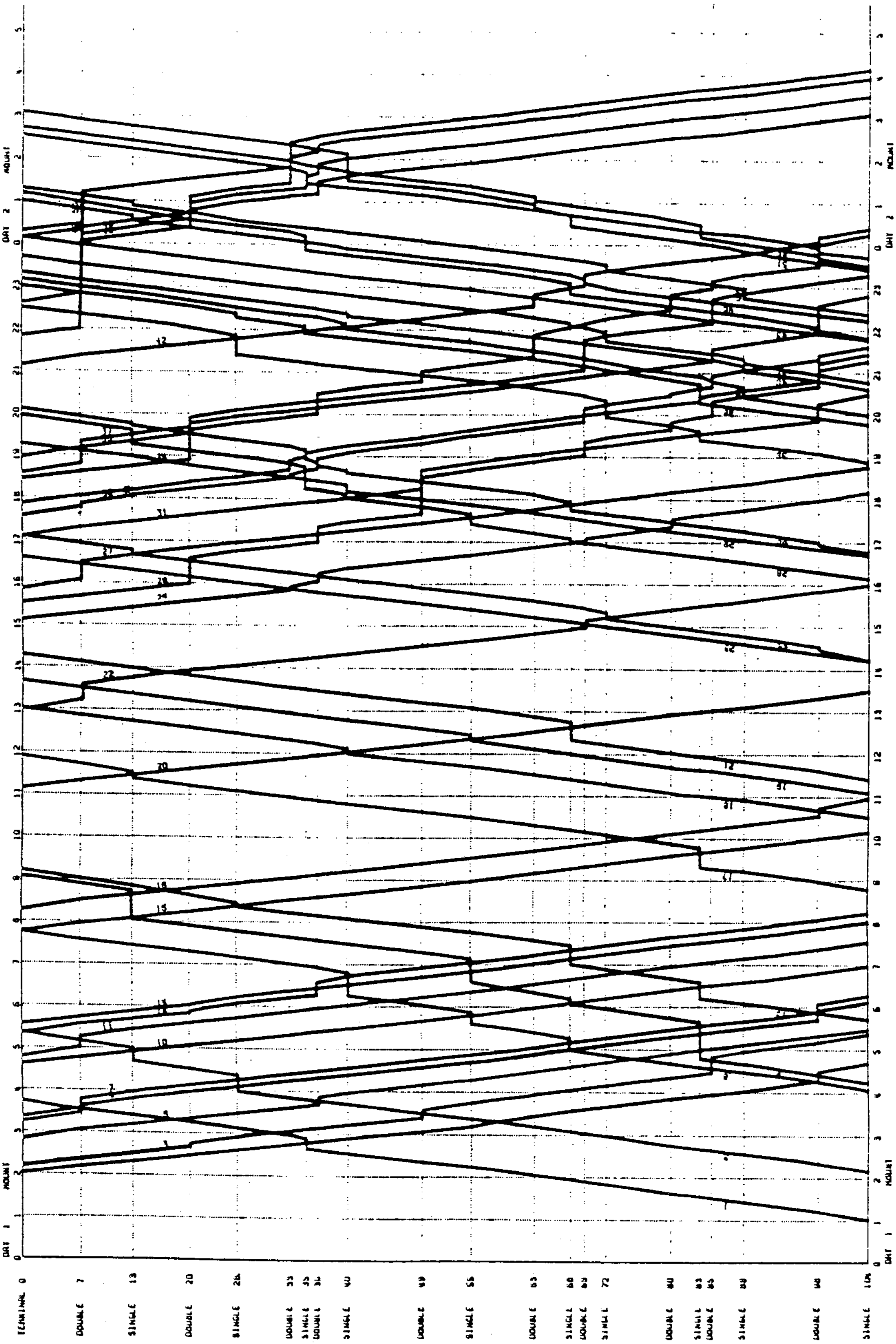

Fig. 1

deviation of 45.3 minutes. In addition, the detailed string diagram was scrutinized by experienced dispatchers from the Canadian National Railways, who verified that the dispatch decisions were realistic.

The simulation required an execution time per day of 1 minute, 56 seconds on a Burroughs B6700, and 3.07 seconds on an IBM 3033.

Examination of the total train delays by segment in this testline clearly indicated that two of the track segments were causing a large portion of the train delays. This indicates the potential for the alteration of the physical plant in these segments to achieve the greatest saving in train delay.

APPENDIX

THE ALGEBRAIC relationships used in the model are reported in detail in this Appendix which supplements the algebraic specification of the model given in Section 3.

The next event train is annihilated if it is a phantom train, or at its destination yard. That is, if

$$\begin{aligned} &l \in PO, && PO = PO\backslash l, \\ &l \in PI, && PI = PI\backslash l, \\ &l \in PM, && PM = PM\backslash l, \\ &l \in OB \text{ and } A_l = M, && OB = OB\backslash l, \text{ or} \\ &l \in IB \text{ and } A_l = 1, && IB = IB\backslash l, \end{aligned} \tag{A1}$$

and the next event is calculated using (2). (The symbol "\" is used to denote the deletion of an element from a set.)

If a track becomes unavailable for service, then a phantom maintenance train is generated to occupy that facility. Thus, for $i \in \psi$, if

$$z1_i \leq x_l \leq z2_i$$

then

$$\begin{aligned} PM &= PM \cup i \\ \psi &= \psi\backslash i. \end{aligned} \tag{A2}$$

To develop the algebraic expressions for the set of available tracks, we consider train l which is currently on track $k = B_l$ of segment $m = A_l$. It is convenient to define the following notation. Let

$$E(l) = \begin{cases} 1, & l \in OB \\ -1, & l \in IB \end{cases} \tag{A3}$$

and

$$G(l) = \begin{cases} OB, & l \in OB \\ IB, & l \in IB. \end{cases} \tag{A4}$$

Then the set of available tracks is given by

$$K(m, k, l, S, K_r) = \{k_1 \mid (KK(m, k, k_1) = 1) \text{ and } (k_1 \in K_r) \text{ and } \forall_{i \in S} [(B_i \neq k_i) \text{ or } (0 < N\{Q\} < b_{m+E(l)})]\} \quad \text{(A5)}$$

where

$$KK(m, k_1, k_2) = \begin{cases} KO(m, k_1, k_2), & l \in OB \\ KI(m, k_1, k_2), & l \in IB \end{cases}$$

is the connection matrix in the direction of travel,

$$Q = \{i \mid B_i = k_1, \quad i \in S \cap G(l)\}$$

the occupants on track k_1 in the direction of travel, $N\{\cdot\}$ is an operator that determines the number of elements in the set $\{\cdot\}$, S is the set (or subset) of trains occupying the next segment, and K_r is a set of reserved tracks in the next segment.

Two occupant sets for a segment are defined. The set of all occupants is given by

$$\theta_2(m) = \{i \mid A_i = m, \quad i \in \eta\} \quad \text{(A6)}$$

while

$$\theta_1(m) = \theta_2(m) \cap (OB \cup IB \cup PM)$$

is the subset of occupants which excludes the inbound and outbound phantom trains which occupy the track for only short intervals.

The set of tracks that train l can physically move onto is

$$K(m, k, l, \theta_2(m + E(l)), \phi), \quad \text{(A7)}$$

where ϕ is the empty set. Tracks that if occupied by train l would result in a line blockage are removed from this set, leaving the set of feasible tracks $F(m, k, l, \theta_2(m + E(l)), \phi)$.

Consider now the expressions that describe the dispatch process. Algebraically we have

$K_r = \phi$ (empty)
$S = \Phi(m + E(l)), x_l, \Delta)$
$i = c(\Phi, m + E(l))$

subject to the constraint that
if $d_m \leq l_i$, then $i = l$.

If $i = 1$
select $\hat{k} \in F(m, k, l, \theta_2(m + E(l)), K_r)$; otherwise
$i \neq l$, let
$R_{A_i} = \{B_i\}$
and for $j = A_i, \cdots, m$ recursively calculate the set $R_{j+E(l)} = \cup_{k \in R_j} F(j, k, i, \theta_1(j + E(l)), K^1)$

where

$$K^1 = \begin{cases} \phi, & j \neq m \\ K_r, & j = m. \end{cases}$$

Then let

$$K_r = K_r \cup R_{m+E(l)}(1) \qquad \text{(A8)}$$
$$S = S \backslash i$$

and select the next i.

Since $l \in \Phi$, this procedure will determine $\hat{k}$, the action train l should take. If the set of feasible tracks is empty, $\hat{k} = 0$ and train l is delayed on the current track; otherwise $\hat{k}$ is the track number train l proceeds onto the following segment.

The state of the system is now updated using the following logic:

If $\hat{k} = 0$:

$D_l = 1$. If $F(m, k, l, \theta_2(m + E(l)), K_r) = \phi$, (that is empty) then let

$$z = \min_{\theta_2(m+E(l)) \cup (\Phi \backslash l)} \{x_k\},$$

the next event time for trains in the contender and occupant set. If $F(\cdot)$ is not empty then the line is blocked, and train l is delayed until the event time of the first nonblocking oncoming train. That is, for $j = m + E(l), m + 2E(l), \cdots$ calculate

$$Q(j) = \{i \mid i \in \theta_1(j) \cap (OB \cup IB \backslash G(l)) \text{ and } F(j, B_i, i, \theta_1(j - E(l)), \phi) \neq \phi\}$$

until

$$Q(j^*) \neq \phi.$$

Then let

$$z = \min_{Q(j^*)} \{x_i\}.$$

The updated event time for train l is then

$$x_l = \max\{z, x_l + h_{lmk}\}. \qquad \text{(A9)}$$

If intermediate signals are available (the number of signal blocks $b_m > 1$), then all other occupants of the same track must also be delayed. Thus if $b_m > 1$, let

$$R = \{i \mid A_i = m, \quad B_i = k\}$$
$$= \{i_1 = l, i_2, \cdots, i_s\}$$

such that

$$x_i < x_j, \qquad i < j,$$

and

$$x_{i_k} = x_{i_{k-1}} + h_{lmk} \quad \text{for} \quad i_k \in R \backslash l. \qquad \text{(A10)}$$

If $\hat{k} > 0$:

$$\begin{aligned} A_l &= m + E(l) \\ B_l &= \hat{k} \\ D_l &= 0 \\ l' &= l + r \\ PO &= PO \cup l', \qquad l \in OB \\ PI &= PI \cup l', \qquad l \in IB \\ A_{l'} &= m \\ B_{l'} &= k \\ x_{l'} &= x_l + \tau_1 + \tau_d + \tau_t \\ x_l &= x_l + t_{l,m+E(l),\hat{k}} + \tau_1 + \tau_2. \end{aligned} \tag{A11}$$

With intermediate signals, $b_m > 1$, let

$$\begin{aligned} R &= \{\, i \mid A_i = m + E(l), \qquad B_i = \hat{k} \} \\ z &= \max_R \{x_i\} \\ x_l &= \max\{x_l,\ z + h_{l,M+E(l),\hat{k}}\}, \end{aligned} \tag{A12}$$

where τ_1 is the additional delay in segment m, τ_2 the additional delay in the next segment $m + E(l)$, τ_d the dispatch delay and τ_t the time for the length of the train to pass the end of the segment m.

The model is now advanced to the next event, with the above process repeated.

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八十八學年度成功大學土木工程學系博士班丁組入學考試

（一）工程構造物分析設計時，首先需依構造實體之行為先做分析模式之設定，依分析模式之應力分析結果進行結構設計，試舉例說明下列事項：(25%)

＜1＞ 分析模式之建立需考慮什麼因素？

＜2＞ 分析模式應包含那些要項？

＜3＞ 分析模式是否會因靜力或動力作用而不同。

＜4＞ 如對建立之分析模式沒有足夠之把握，應如何進行分析模式之修正工作。

＜5＞ 工程構造物施工完成後，應如何再進行分析模式之修正。

（二）一 RC 簡支梁，中點受一集中荷重，此集中荷重由零開始逐漸增加至破壞。試述此梁受力歷程之力學行為。(25%)

（三）混凝土中孔隙率高低將如何影響混凝土之彈性模數，抗拉強度及抗壓強度？如何減少孔隙率？（25%）

（四）試由均佈荷重作用於含裂縫之薄板 (如下圖), 說明有限元素法(FEM) 及邊界元素法(BEM) 之應力分析過程. （25%）