SIMULATION OF A RAILED AUTOMATED HIGHWAY

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SUMMARY

This paper is concerned with a useful application of simulation to aid the systems design of a high speed inter-city ground transportation system. The approach simulated utilizes a computer controlled constant speed main-line railed vehicle carrying occupied vehicles, freight, and passenger modules. Shuttle trains mate with the main-line trains at transfer points, and simultaneously transfer vehicles on and off the main-line train at full speed. The simulation results showed the minimum headways possible for the various shuttle configurations under study, the vehicle handling capacity for the different configurations, and vehicle speed through the system. GPSS/360-NORDEN was used with its ability to use the 2250 display unit. This facilitated the development of systems studies.

INTRODUCTION

There is a need for an inter-city surface transportation system able to carry passengers and freight from and to many places. Further, the system must operate over a wide range of distances without peak-hour choking of highways or creating congestion in urban areas. Among the constraints on such a system are: high average speed independent of driver skill or automobile condition, freight and passenger operations, high lane capacity under all weather conditions, safety exceeding that of the auto-on-highway system, limited environmental degradation, and economic visability.

Many electronically controlled or automated highway systems have been proposed. The great majority of these systems use the private automobile or truck as the vehicle. This approach is hampered by the unreliability of these vehicles at sustained high speeds due to inadequate maintenance, the risks due to inclement weather, or the high fuel consumption rate per passenger mile.

One suggested advanced system concept for intercity ground transportation uses a main-line railed vehicle, traveling at constant high speed (120 to 150 mph). This vehicle would travel between distant terminal points and would carry occupied automobiles, freight, modules and passenger modules. Service for intermediate points would be provided by transfer of modules to and from the speeding main-line vehicle by shuttling station vehicles capable of mating with the main-line vehicle on its passage through each "station". The station vehicle would serve main-line travel in opposing directions. Loading of station vehicles and module transfer on and off the main-line vehicle would be computer controlled, and the transfer would be completely automatic.

The novelty, cost, and mechanical and operational complexities of such a concept require a comprehensive system analysis to determine general feasibility. The operation of 120-150 mph railed vehicles is well within the technical state of the art. Likewise, the computer control system and propulsion system are feasible. But the economic feasibility is uncertain. A computer logic model was developed, therefore, that would simulate the behavior of such a system and permit analysis of trade-offs of capability and transport time versus required facilities. From this model, some of the capital investment requirements were obtained. These requirements are dependent upon such factors as system capacity, load factor, passenger demand, spacing between stations, number of shuttles at stations, and frequency of service.

DESCRIPTION OF MODEL

A computer logic model, written in the GPSS language, simulates a two-track railroad system consisting of main-line trains of specified vehicle-carrying capacity, traveling at a selected cruise speed under stated headways. Transfer points are located at various distances along the main-line tracks where shuttle trains mate with main-line trains and simultaneously transfer autos on and off, without slowing down the main-line trains.

The model can handle an essentially unlimited number of transfer points and is not limited to one shuttle per transfer point. Also, the shuttles can be arranged to travel either in an oval between a transfer point and a vehicle loading terminal, Figure 1, thus serving traffic in one direction only, or they can travel in a hysteresis-type loop, Figure 2, between the transfer points and the vehicle loading terminals, thereby alternately serving traffic in each direction.

The model was constructed with the number of transfer points as an input; thus, the logic is independent of the number of transfer points. Four transfer points in each direction and a terminal at each end are used in the operational model because passenger demand data[1] were available for a configuration of this type.

The analysis investigated both the oval shuttle of Figure 1 and the hysteresis loop shuttle of Figure 2 using one model. This is accomplished by having the shuttle type number and characteristics as input information. Not only were the two types of shuttles investigated, but different numbers of shuttles were introduced at the transfer points. Another investigation concerned altering the number of shuttles at the various transfer points according to time of day, reflecting increased demand early in the morning and late in the day.

Throughout the simulation, at six-minute intervals, groups of autos are generated at each transfer point and terminal, one group for each destination served. The number of autos in each group is governed both by the stated total daily demand between particular terminals and by the specified time distribution of that demand.

The passenger demand data used were the actual 1960 demand for the system configuration under study and a 1980 demand suggested by a "gravity model" of this system configuration. These demands were put into the model by the use of two FUNCTIONS. One FUNCTION is the daily demand between every two points in the system, and the other FUNCTION is the time variation of that demand. A VARIABLE statement combined the two FUNCTIONS and other pertinent data, and generated the required number of vehicles at each interval. The interval used for the operational runs of this model is six minutes.

Obviously, a vehicle cannot be loaded into a position on a shuttle if that position is already occupied by a vehicle on the main-line train. Thus, the shuttle must have knowledge of the positions available on the main-line train. The logic of the model is such that as each main-line train leaves a transfer point, it communicates to the shuttle serving the next transfer point and passes on the available space information.

Each main-line train transfers information to only one shuttle at each transfer point. This is accomplished by testing each available shuttle as to whether there is sufficient time to load the shuttle and meet the main-line train. When a shuttle that meets this criterion is found, the information is transferred, and no ther shuttles are tested. The shuttle now allows the waiting vehicles to board the slots that will align with available slots on the main-line train. The transfer gear under consideration does not allow the loading of a slot that is being unloaded at the transfer point in question. This means that the main-line train is required to travel with a number of unfilled slots except when it leaves the initial terminal.

Main-line trains are generated in the model at specified intervals at each end of the system. This model was developed to examine a large netword with the emphasis on examining only a portion of it initially; therefore, the main-line trains are partially loaded with vehicles traveling to various destinations within and beyond the portion of the system to be examined. Later use of the model was for a small system - 2 terminals and 4 transfer points - where preloading was considered as vehicles boarding at the terminals. These data are part of the demand data required. These main-line trains then proceed toward their initial transfer points, contact the appropriate shuttles, and transfer information as to available space.

The initial problem in any arrangement is to determine the smallest permissible interval between main-line trains. Since this is independent of passengers or freight, the model has been so constructed that the portions of the model dealing with passengers and freight can be "shorted out", thereby reducing the running time. Once this is determined, various demands can be investigated.

One of the most important results of this study was the information obtained regarding the relationship of the shuttle configurations and main-line train intervals. The main-line train interval determines system capacity when the main-line train capacity is fixed; therefore, various shuttle configurations as to shuttle loop and the number of shuttles at each transfer point were studied to determine their effect on main-line train headway.

Shuttles are generated and placed in the terminals, where they await the transfer of information as to which spaces will be available for transfer of vehicles to and from the main-line train. When this transfer has been made, the shuttles permit waiting and arriving vehicles to board the shuttle. Statistics on the delays encountered by the vehicles are tabulated.

The main-line train signals when the shuttle must cease to load and must depart the terminal in order to accelerate to cruise speed and mate with the main-line train.

At the transfer point, vehicles are transferred on and off the main-line train. Then the shuttle proceeds to the terminal, either back to the same terminal (as in Figure 1) or to the terminal serving vehicles in the opposite direction (as in Figure 2). Once back at the terminal, the vehicles are unloaded and the shuttle again awaits space information from the next main-line train.

The model generates output which is available both on a 2250 Display Unit and from the printer. This output, using the Report Generator feature, lists certain input information such as number of transfer points, distances between points in the system, shuttle and main-line train characteristics, and number of shuttles per transfer point. Additional output is generated, such as average speed between system points, length of simulation, number of main trains generated, passengers (vehicles) entering the system, passenger mean speed through the system. Statistics, space, and passenger information are available in matrix savevalue form.

CONTRIBUTIONS OF THE MODEL

The main contributions of the computer logic model to the comprehensive system analysis were:

- Problem Definition. As the transportation system was a concept rather than a reality, the ground rules for the system were not clear. Development of the model raised many questions concering the proposed system. These questions and their answers were instrumental in bringing the system to its present state.
- Insights Into the Relationships of the Various Components of the System. Insight was gained as to the critical areas of system operation - which areas the system was sensitive to, where large changes caused minimal effects, and where small changes caused great effects.
- Data Upon Which to Base System Schedules. These schedules were used as the basis for the economic and feasibility studies. The schedules determined system capacity which, combined with input demand, helped produce the system load factor and passenger miles upon which to base revenues. The schedule was also used to determine rolling stock requirements and operating expendes. Another important result was the passenger speed in the system, where the figures obtained showed promise for future study.

Areas for Future Study. These included several methods of increasing system capacity and effect on revenues of adding freight service.

CONCLUSION

A system study of this type benefits from close interaction between the system study group and the computer. This was achieved by using GPSS/360-NORDEN with its man-machine interactive capability that uses the 2250 display unit. In addition, when this type of system problem is simulated, the large amount of data generated within the model often exceeds the available core. These data were readily handled using the GPSS/360-NORDEN feature of matrix savevalues on disk.

Simulation provided the means of gaining insight into the various facets of the problem under study. It was the only tool available that permitted investigation of the operational characteristics and system load factor with the interactions of the main-line train, the shuttle, and the passengers. Simulation was thus able to contribute a prediction of operating cost to the overall study of a high speed automated railed highway.

REFERENCES

[1]Anon: Demand for Intercity Passenger Travel in the Washington-Boston Corridor. Systems Analysis and Research Corporation Report prepared for U.S. Department of Commerce, undated

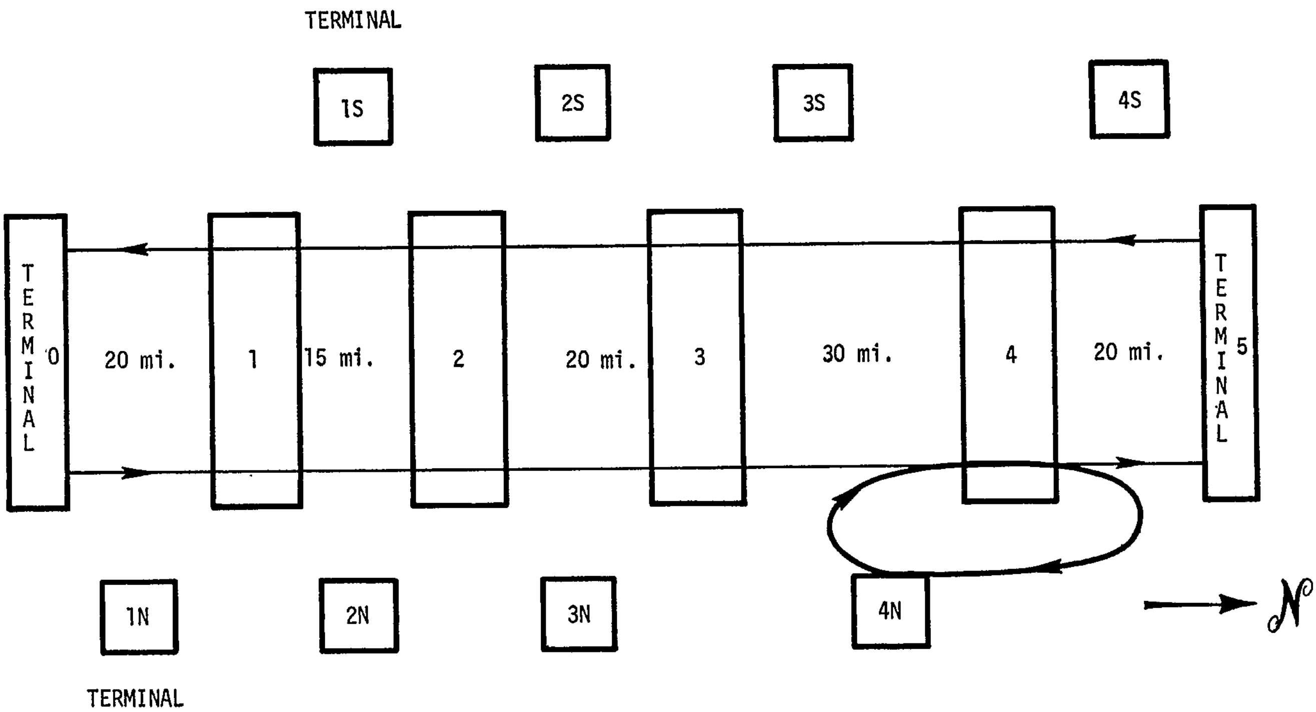

Figure 1. Oval Loop Shuttle

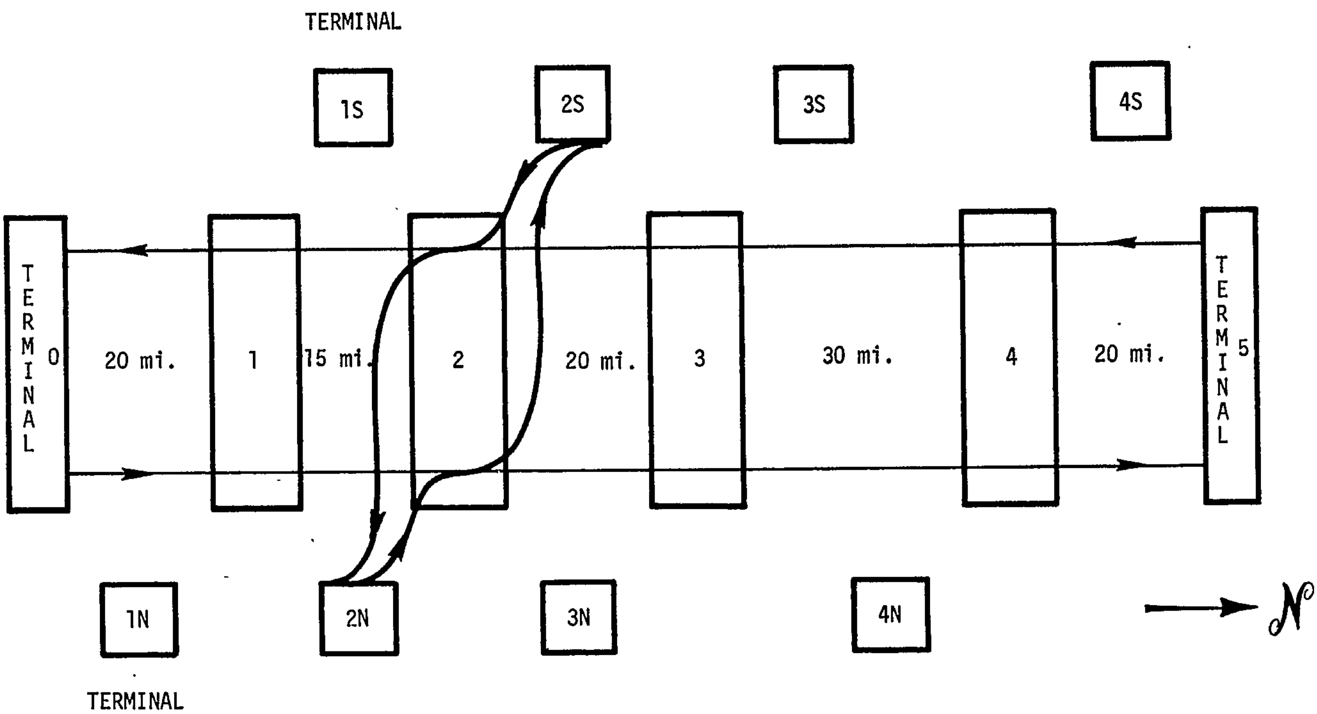

Figure 2. Hysteresis Loop Shuttle