Planning the C & O's CLIC-

In this paper, presented before the AAR Communications Section Convention in Detroit, Mr. Flanagan explains the methods the C&O used in estimating costs of the communications system required for their Car Location Information Center.

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● This paper deals with some of the economic aspects of data handling as related to communication. It is based on experience gained through association with our data handling program on the Chesapeake and Ohio Railway. A program conceived at a general staff meeting during July of 1953 that resulted in the formation of a task force immediately thereafter to study and recommend suitable circuits and equipment to implement mechanized handling of car information.

At the beginning of our Alice in Wonderland adventure in data handling we were most intrigued by what was then known as the "One Shot Method" approach. Simply stated, in case it may be lost in antiquity, it was then described as a method of operation wherein the initial manual conversion of data from the source document to a machine language would suffice for all subsequent operations. Having selected the document, in this case the train waybill and the data processing system, IBM punched cards, we were ready for the simpler things. To wit, things like how to transport data on some 4,500 or more cars a day from 275 separate locations to a data handling center, and at the same time deliver one or two lines of information on all cars passing from yard to yard prior to train arrival.

From July of 1953 through the year 1954 the task force group studied various phases of the over-all problem. Early in 1955 recommendations were made that a system teletype network be provided as the communication link to be used, with the IBM card handling equipment decided upon as the data processing medium.

To better detail and determine our specific requirements the over-all project was broken down into four, more or less separate and distinct, categories:

1. Input, including points of pick-up, volume expected at each point, time available for data preparation and tolerable delay in transmission.
2. Output, including the form in which data must be delivered to the processing center, timing and consequences of errors in data preparation or transmission.
3. Data Processing, including volume expected, time available for processing and the form in which it must be compiled for distribution.
4. Distribution, including points that will receive information, volume to be delivered to each location and revertive traffic load expected to result from original delivery of information, or requests for information not initially provided.

A separate study was also made of the possible labor implications of changing from one type of operation to another. A most important consideration if a project is to be consummated with any degree of permanent satisfaction.

Only items one and two, Input and Output, will be discussed here, as these involve the communication facilities. The chart in Figure 1 shows graphically some of the important factors that must be considered to plan an adequate teletype facility to handle consist information. In this instance the train consist furnished the basic data from which various operating, sales and accounting information will be derived.

Figure 1 illustrates the progress of a single manifest train from yard A to yard B, yard B to yard C, yard C to yard D, then eastward to yard E. Actually, in this case, yard A and yard E may be considered main terminals, yard A being a point where a train i made up and yard E where it is com pletely reclassified and one or mor new trains formed.

Time, as associated with train move ment and yard operations, is indicate by a 24-hour clock at the left.

Starting at the top left hand sid of the chart at yard A you will not that 79 cars were received in inter change at 500 or 5 AM, and that th train departed at 630 or 6:30 AM The cars received in interchange wer in the yard one and one-half hour a indicated by the vertical line from 50 to 630. The time required to prepar unit tapes on each car and run off master tape for line transmissio amounted to approximately 53 min utes, as indicated by the short vertica line to the right of the cars receive in interchange line. On completion o the master tape, line transmission wa started immediately as shown by th horizontal arrowed line to the right The consist is received in complete form at yard B at 615, or about fiftee minutes before train departure fro yard A. The information is simul taneously received at CLIC, the Ca Location Information Center. In thi case the transmission is shown as be ing made at 75 WPM, consumin about 26 minutes of line time.

As a general rule we found tha there was adequate time to prepar and transmit consist data from a originating terminal to the next inter mediate yard well in advance of th trains arrival, as in this case from yar A to yard B.

Problems at Intermediate Yards

At intermediate yard B the situatio is a little different. Here, we have o hand the tape and hard copy for switch list received from yard A wel in advance of the trains arrival, an sometime later we receive the way bills on the 13 cars picked up locall and proceed to prepare unit tapes o these cars. Now, that is about as far a we dare go until the train has arrive and we have determined that ther were no pick-ups or bad order set-off enroute, and until the 13 cars received locally have been switched into th train and the train checked as to ca order. Usually the train check list i

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vailable about the time of train departure or shortly thereafter. The master tape is then prepared and line transmission begun as indicated by the short vertical line and horizontal arrowed line to the right of yard location B. For all practical purposes the same routine is followed at intermediate yard locations C and D, and at terminal E.

Number of Information Lines Vary

For all cars originating on line or received in interchange the equivalent of 2 or 2½ lines of information is transmitted to the next yard and direct to CLIC. However, the next yard requires only the first line of information for operational purposes. This makes it necessary for each intermediate yard to tear the continuous tape received from another yard into unit car tapes, delete line two and any additional information, and store until all waybills on cars received locally are available and two line tapes have been cut. When this has been done and the train order determined a master tape may be cut for line transmission.

With the exception of the tape received from yard A, which contains all two line reportings, all other tapes received at the Car Location Information Center will generally have both originating, two line information, and passing, single line information, in varying order depending on location of cars in the train.

Referring to the word count column at the extreme right hand side of the illustration, you will note that the word volume for each train movement from yard to yard is indicated. There are 123 two line reportings on cars received in interchange or locally along line, and 249 single line passings reported, or a total of 495 lines of information, equivalent to roughly 5,940 words. The total words received at CLIC amounts to 9,180. The difference of 3,240 words covers addresses, statistical headings, summary and signature, etc., required to identify transmissions for operational and data handling purposes.

In a general way this describes the movement of a single train over a given route. In actual operations there will usually be several train movements taking place simultaneously on a given territory in any 24 hour period. Trains will be moving in both an eastbound and a westbound direction and arriving at yard locations at various times determined by schedules and operating conditions. Experience has shown that it is possible to predict, with a fair degree of accuracy, the arrival and departure time of trains at yard locations if the past train performance records are studied for a representative period of time. Actually, this is one of the more important considerations in determining circuit requirements, in that the handling of peak period word volume without undue delay is a must if the system is to function with any degree of efficiency.

A very simplified version of a composite of several train movements over a given route is shown here in Figure 2. In this case we have four trains, two eastbound X and Y, and two westbound X and Y, operating between yards A and E, and passing through yards B, C and D enroute. The black vertical lines, as an example under eastbound train X, between A and B, represents the time available to prepare consist data and transmit it, in this case from yard A to yard B. The same is true for the vertical lines under eastbound train X between yards B an C, etc. The measure of time denoted by the vertical black lines consists of a com-

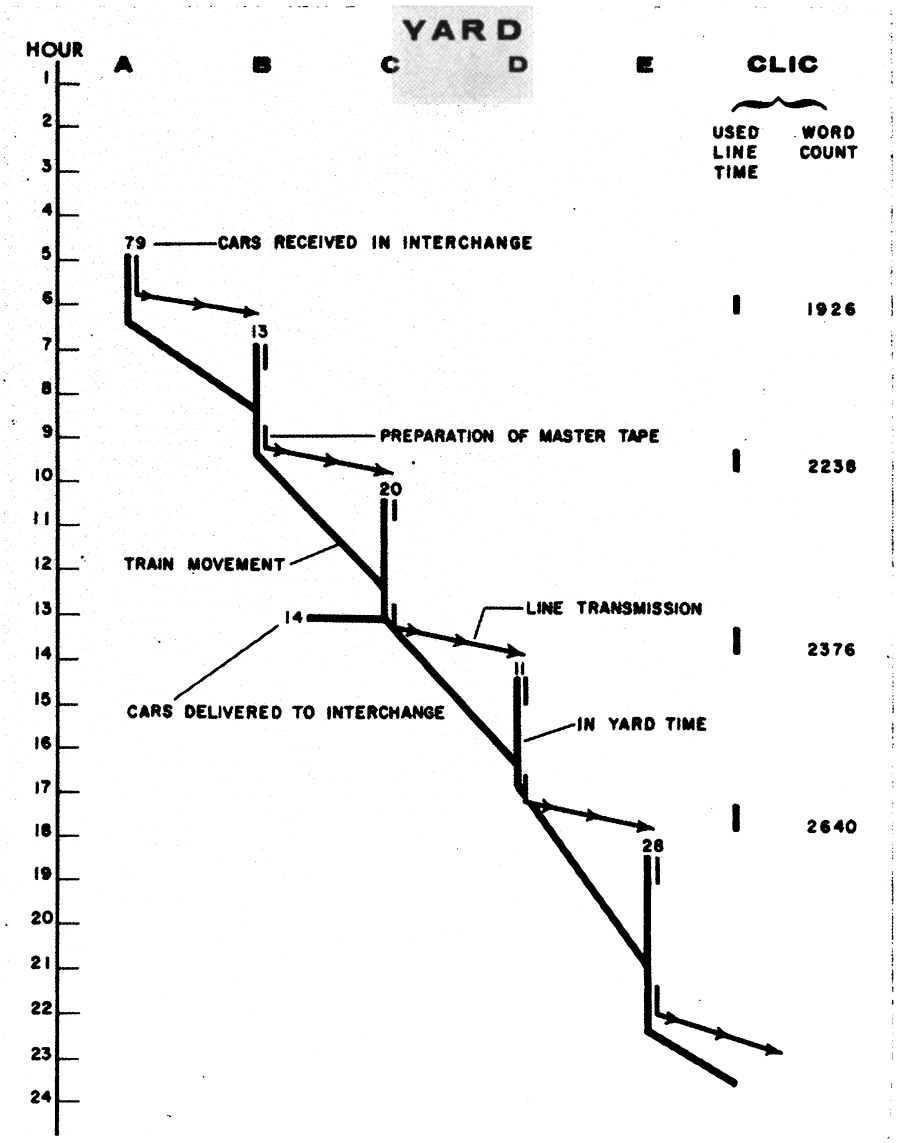

Figure 1: Consist preparation and transmission as related to train movement.

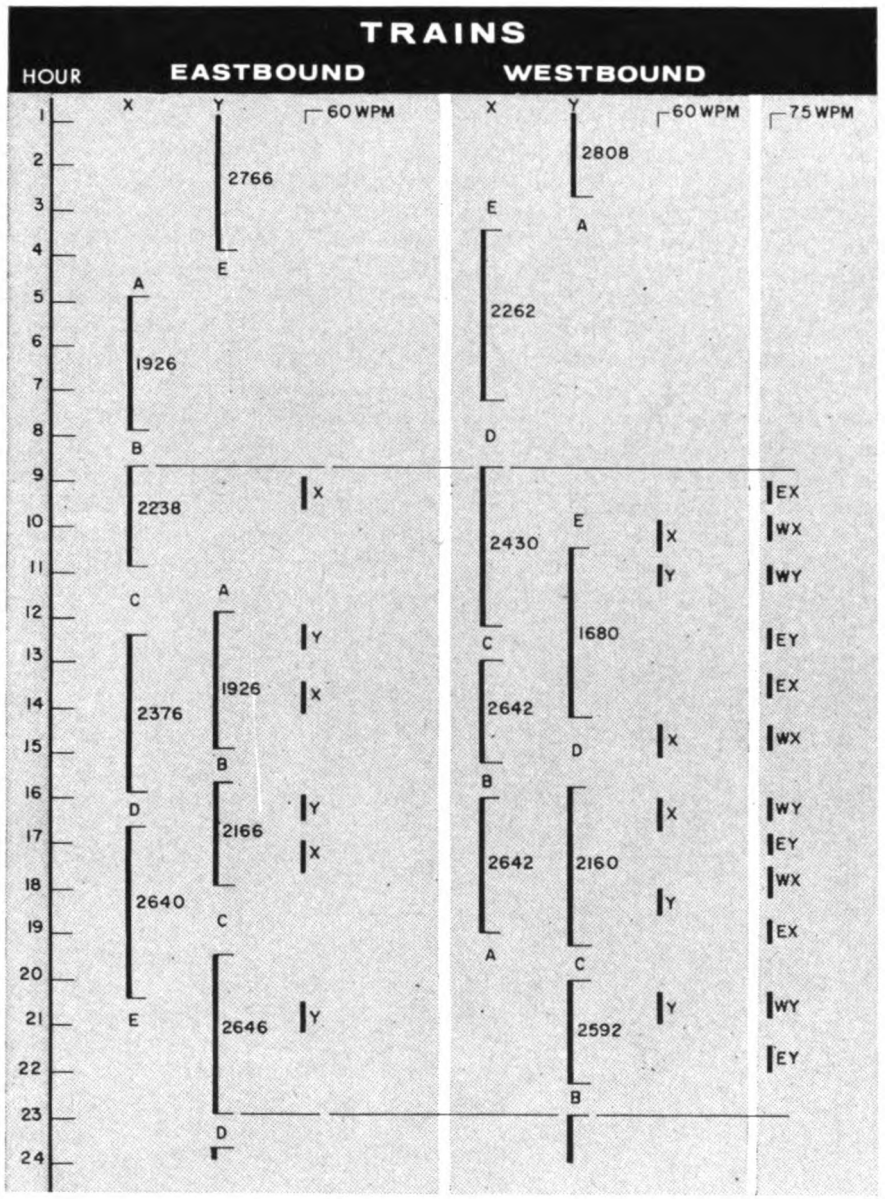

Figure 2: Time available to prepare and transmit consist data for several trains.

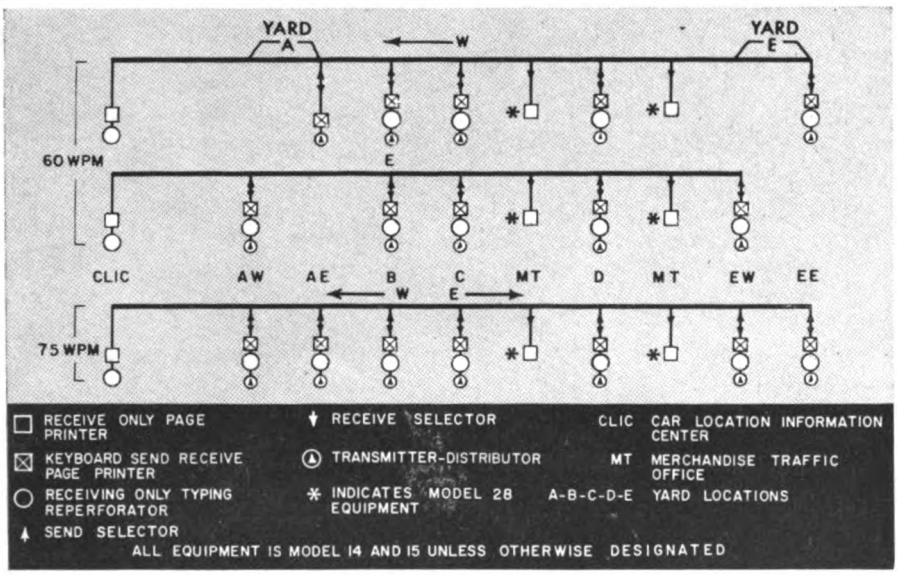

Figure 3: Comparing equipment needed for operation at 60 and 75 words per minute.

bination of several things. First, when the preparation of a consist could conceivably start, or when the information necessary to permit tape preparation should be available to the yard. Second, a portion of the trains running time between yards, or the cut-off time when consist tape must be transmitted to the next yard to assure its receipt sufficiently in advance of train arrival to permit switching and yard handling. Generally stated, the vertical line represents the amount of time within specified periods wherein certain data handling operations must be completed. For purposes of reference the word volume is indicated for each operation to the right of the vertical lines. As an example, between yard A and B, under eastbound train X you will note 1926 words are shown. Such a layout serves only one purpose, the determination of peak load periods.

In this particular case, train movement density fell between the hours of approximately 845 and 2300, using the 24 hour clock. Converting the words to equivalent time intervals for 60 WPM operations, you will note under the eastbound movements that there is no apparent load problem. The same holds true for the westbound movement at the word volume indicated and 60 WPM operations. However, a combination of both eastbound and westbound consist traffic on a single 60 WPM circuit, could under conditions of train delays, line trouble, and other unforeseen conditions, result in accumulative delays that would defeat the purpose of the system. Equating the same word volumes into time for 75 WPM speeds indicates that, as a minimum, a buffer insurance in time of at least 50% under normal operating conditions should be provided. Our actual experience indicates that this is a reasonable minimum figure. Any less allowance for contingencies will surely result in excessive delays as a rule rather than as an exception.

Based on the peak load periods and need for additional line time to take care of contingencies we have our choice of two or more possible circuit configurations to fill the consist traffic conditions graphically illustrated in Figure 2. For purposes of discussion let us say that we consider either two 60 WPM circuits or one 75 WPM as sufficient to fulfill our requirements as shown here in Figure 3. First, it is to be noted that if we assign one of

ıe two 60 WPM circuits as a west-ɔund circuit and the other as an ıstbound circuit some savings in ɟuipment may be achieved. This is rought about by the fact that at yards here we have separate eastbound and estbound yard office, and the consist ıformation follows the flow of traffic, ansmissions would be from an east-ɔund yard office at one location to ıe eastbound yard office at the other ɔcation. The same condition of course eing true for westbound train and ɔnsist movements. However, at yard ɔcations where all clerical work is onsolidated in a single office it is ecessary to provide equipment on oth circuits.

With 75 WPM operations as shown ı the lower circuit layout plan, worth-ɣhile savings in equipment will be pos-ible. This is a very desirable objective s the major cost for leased teletype acilities at this time may be assigned o equipment.

Relative Costs of Equipment

The relative cost for two 60 WPM circuits as compared with a single 75 WPM circuit is shown in Figure 4. It will be noted that the rental difference amounts to $789.94 monthly. The theoretical capacity of the two 60 WPM circuits operated 24 hours a day 30 days a month is about 432,000 lines of information. Based on a monthly rental of $2,278.30 this works out to be about $0.0053 per line of information. The theoretical capacity of the single 75 WPM circuit is around 270,333 lines of information at a cost per line of about $0.0055. And to carry the matter further, if 100 WPM operations were considered the capacity would be 360,000 lines at a cost of about $0.0049 per line.

In the particular circuit under consideration the actual requirements were for a circuit that would provide a working capacity of 3,000 lines with an equivalent of 1,500 lines of spare time each 24 hours. On the basis of a 30 day month this would amount to 135,000 lines of information. The approximate cost per line of information for this particular load requirement at the various operating speeds is: two 60 WPM circuits, $0.017; one 75 WPM, $0.011; and one 100 WPM, $0.013. This serves to point up the fact that line circuits and equipment should be engineered as close as possible to actual service requirements when leased facilities are employed for data handling purposes.

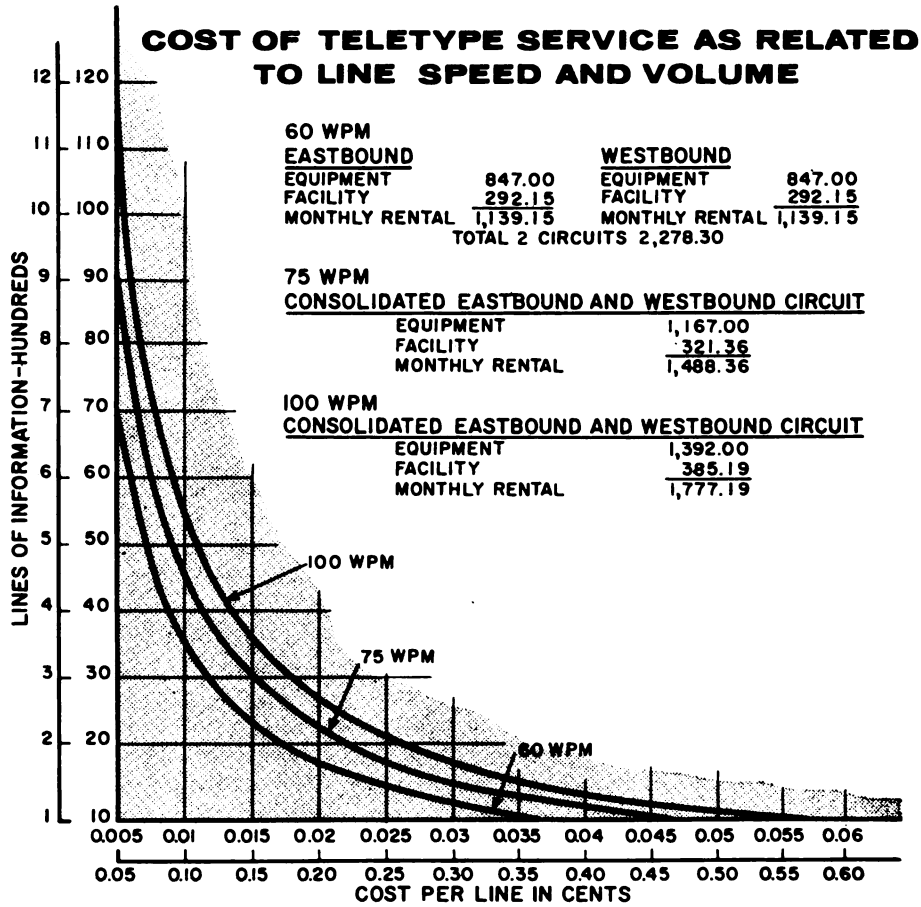

Figure 4: A graph of facility cost per line, at several speeds, for 24 hours.

Figure 4 also includes a graph of cost per line of teletype information based on 60, 75 and 100 WPM operations. This graph represents volume figures for a 24 hour period and prorated facility cost of the same interval. Inasmuch as this graph was based on the composite facility cost for all leased teletype service used in consist data handling, it has proven of some value in determining average cost for service based on day to day volumes. It also permits a rapid determination of when consideration should be given to changes in circuit operating speeds, either upward or downward.

The standard data preparation equipment in our yard offices consists of an assembly of conventional teletype equipment units. The various pieces of equipment being physically arranged to permit the convenient conversion of waybill information into five level teletype tape.

The essential units required are shown in Figure 5, and consist of a Keyboard Send-Receive Page Printer, an Automatic Tape Transmitter-Distributor with end of tape switch and tape release lever (free wheeling gate), a Typing Reperforator with tape back spacer and a local battery supply. This small amount of equipment, sufficiently compact to fit into the smallest yard office, will permit the manufacture of consist data in a legible form for yard to yard operational purposes, and at the same time provide a suitable input for data handling equipment.

The typical current average rental cost for such equipment when obtained from an associated Bell company is approximately as follows:

15 KSR Page Printer	$30.00
14 ROTR with tape back spacer	25.50
14 ATR with end of tape switch and tape release lever	20.50
3 75 speed charges @ $2.50	7.50
	$83.50

The listed charges are about average charges for equipment, based on tariffs in effect for ten of the associated Bell companies operating in the vari-

ous states the C&O serves. As an example, the rates for a model 15 Page Printer varies from a low of $25.00 for one company to a high of $35.00 for another company. The over-all rental cost for a basic teletype tape factory is very low and including fanfold sprocket feed paper, teletype tape and ribbons for the printer and typing-reperforator, probably represents a minimum for a workable data originating station.

Some of our studies indicate that the average cost per line of information (equivalent to seventy two characters or twelve words), including equipment rental, paper, tape and ribbons is about $0.0025 or $0.005 per car per reporting location, based on two lines of information for each car.

In this particular study labor costs at yard locations were not considered, as the operation did not require additional manpower or permit a reduction in existing forces. Let us say that it was a case of engineering a work load to meet a labor situation, and obtain in the process a worthwhile by-product. The by-product being a teletype tape suitable for line transmission and data processing.

While the usual mixed train consist probably represents better than 85% of the total data prepared and transmitted on line, there are a few consists such as an ore train consist that contains a large volume of repetitive information. Ore trains are usually solid trains loaded from one ship and billed to a single destination. All of the information after the heading and following each individual car initial and number is identical and lends itself to automatic insertion in a master tape.

Teletype equipment readily lends itself to special adaptations for data handling purposes. One of the simpler modifications, taking advantage of the Stunt Box functional selector mechanism incorporated in a 28 KSR machine, is the fixed programmed tape factory shown in Figure 5. The term "programmed" being used in the sense that certain assigned functional operations have been added to the assembly to perform a given task. As will be noted, this assembly of equipment consists of a 28 KSR machine with Stunt Box, a 14 Typing-Reperforator with tape back spacer, a 14 Multiple-Gate Transmitter-Distributor with end-of-tape switch and tape release lever, a relay control cabinet and local power supply. This assembly will perform several very useful data handling operations.

In addition to functioning as a standard tape factory for the preparation of consist tapes for unit records and preparation of a master tape for line transmission, the arrangement will also permit the insertion of repetitive information in a continuous tape in format when non-repetitive information is fed into gate number 3, and the repetitive information in a loop tape is in gate number 1. The operation is such that functional switching characters punched in the tape containing variable information, and similar functional characters in the loop tape to perform flip-flop switching, are either absorbed in the switching operation or appear as blanks in the output tape. The tape thus prepared is clean of functional character codes that could interfere with transmission on a sequential calling automatic start teletype system, switching through a relay center, or effect operations of IBM 047 tape-to-card machines. A good example of the use of this arrangement of equipment is the insertion of repetitive information in an ore train consist.

The preparation of master tapes from unit car tapes is also expedited by the alternate feeding of unit tapes into gates number 2 and number 3. In this case the automatic start feature of the alternate gate containing a tape is initiated by the end-of-tape switch on the gate in operation.

At present, the typical average monthly rental cost for such equipment when obtained from one of the associated Bell companies runs about as follows, for 75 WPM operations:

28 KSR with sprocket feed platen	$35.00
14 Multi-Gate Transmitter-Distributor with end of tape switches and tape release levers	55.00
14 Typing-Reperforator with tape back spacer	25.50
Stunt Box and Relay Control	10.00
3 75 WPM speed charges @ 2.50	7.50
	$133.00

This cost represents an increase of $49.50 in monthly rental over the cost for a conventional tape factory as previously described. The justification for this increase is easily achieved in that through its use it is possible to perform approximately 33% more work over a 24 hour period when the handling of repetitive information, such as preparation of ore consists, is necessary. In other words you might say its use added the equivalent of one man twelve days a month, that would have cost $233, not including overhead.

Studied Use of Transceivers

Some very limited studies were made of the use of IBM Transceivers for consist data handling. In the study the transceivers were used on a full period leased telephone circuit arranged for alternate talking and data handling service. In this manner tests could be conducted on transmission speeds, error rate and effect of various machine programming during the hours when the circuits used for conversational purposes were at a minimum. The tests indicated that the type of programming employed could materially effect the transmission speed. The results of some of our tests are indicated in Figure 6. This graph indicates the results of a series of short tests made for the purpose of establishing machine running time of various programs. Groups of 25 or 50 cards were transmitted, using more than 150 different programs, and the elapsed time of each run recorded.

The curves in Figure 6 were developed from the results of these tests. They may be used to approximate the number of cards produced per hour where the operations are synchronized column for column between transmitter and receiver. The curves are based on a single field of skipping or duplication at different positions of the card as indicated. Although the card volume increases as the number of columns skipped or duplicated increases, the number of characters transmitted per hour decreases. Thus, the most efficient operation in terms of telephone circuit time is 80-column transmission and reception.

The number of cards produced by operations where there are two or more fields of skipping or duplication may be approximated by locating the point on the curve which would be

the output if there were only one field of the same total length. The result thus obtained should be reduced by about 5% for each restart more than one in the program.

Programming would have been of considerable benefit had it been possible to use it in our operations. However, in our case, to accommodate all the information required for an original reporting would result in the use of two 80-column cards. Our requirements were, for all practical purposes, equivalent to two lines of teletype information, or the equivalent of at least 120 characters. This would mean a minimum of two 80-column cards would be required, and as programming can only be accomplished on a single card basis, this desirable feature could not be used. We did study the possibilities of transmitting single line passing report information using a synchronized column for column program for 72 columns, skipping from column 73 through column 80. The effective speed was found to be about 130 words per minute, or eleven IBM cards.

Including rental costs for Manual Card Punch, 066 Reading and Punching Unit, 068 Telephone Signal Unit, IBM cards and circuit facilities, the cost per line of information was calculated to be around $0.028.

The equivalent cost for teletype service at 75 WPM was calculated to be about $0.005 for local tape preparation and $0.011 for line transmission, or a total of $0.016 per line per transmission. The difference of $0.012 per line in our case would have resulted in an increase of over $8,000 a month based on the average volume of 675,000 lines handled.

Evaluating Labor Costs

Attempts have been made to evaluate and compare the labor costs involved in the various operations, that is teletype, IBM Transceivers, and combinations of these operations. So far we have not been successful in arriving at dependable figures. To properly produce reliable cost figures on such work it is necessary to determine actual division of each yard clerk's time between data handling tasks and other tasks. An individual study of over 425 positions with varying wage scales would be necessary. The time has not been available for such a detailed study. It is sufficient to say that the conversion to teletype data handling for all practical purposes was done in the yard offices without need for increases in manpower. Our study of the cost for communication facilities assigned to data handling is a continuing program, and it is expected to produce additional savings in communication facility costs without a reduction in data handling efficiency.

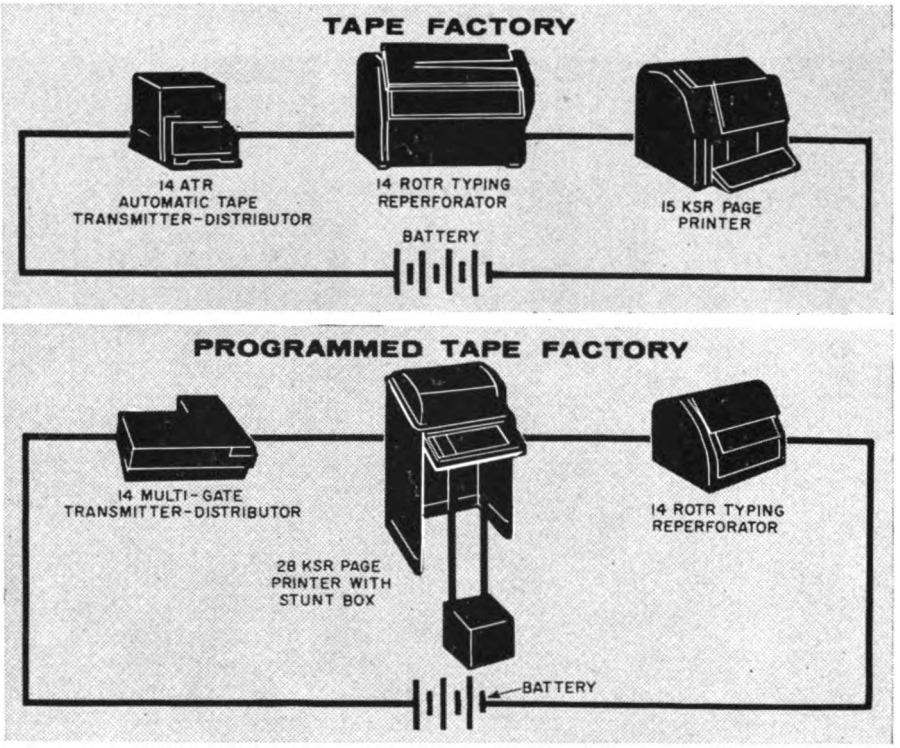

Figure 5: Average monthly rentals: Tape Factory, $83.50; Programmed Factory, $133.00.

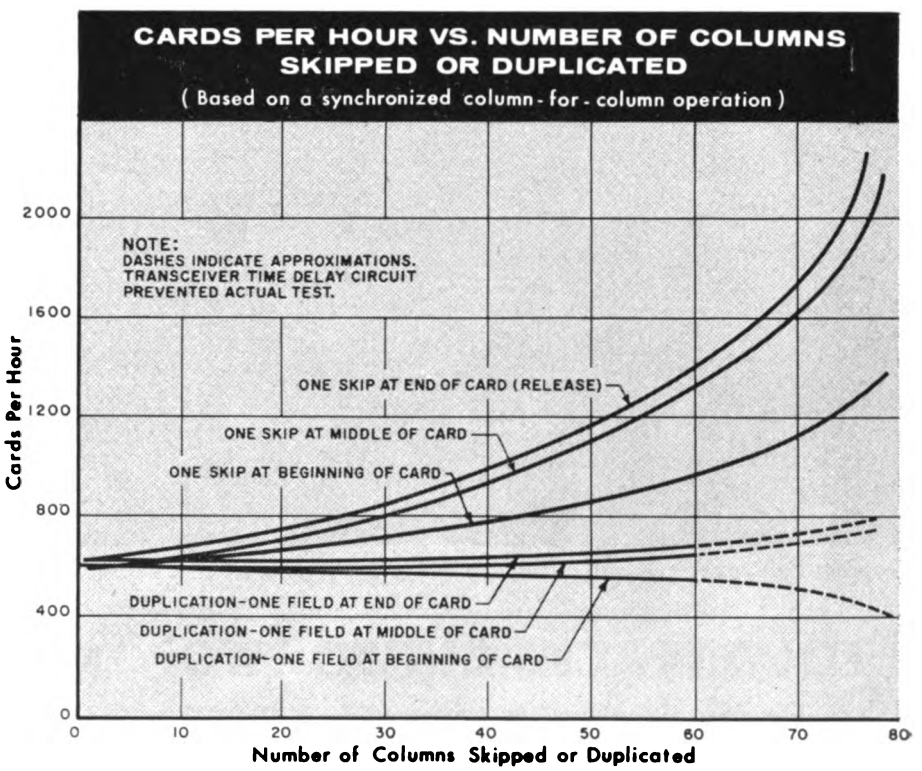

Figure 6: Transceiver card output. Full 80 column transmission is most efficient.