

Applying Statistical Process Control Methods in Railroad Freight Classification Yards

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Quality experts and rail customers have long admonished rail management for the need to improve service reliability and consistency. Investigation has discovered that most of the variance in rail transit times, wrongful charges, and so forth stem from origin, intermediate, and destination yard procedures and information processing. Although there are known problems, little constructive assistance is typically offered in the literature. The use of statistical process control (SPC) quality tools to address this common railroad problem is discussed. A brief explanation of SPC is followed by an examination of a typical rail freight classification yard and discussion of how these tools can be used to identify and prioritize problems. Special emphasis is placed on the need to bring these yard operations under control, thereby eliminating special causes of variation. With yard operations under control and predictable, rail operations can work on common causes to improve service delivery. Management can then redesign procedures to structurally improve the systems process. Both approaches are necessary to attract quality-conscious shippers. Procedures include the use of flowcharts, control charts, and Pareto analysis. Implications for management are also discussed.

Accompanying the widespread renewal of interest in quality management by North American businesses has been increased interest in ways to apply these procedures to service industries as well as more traditional manufacturing applications.

The idea of measurement of service levels in the railroad industry is not a new one. Landow and Wharton advocated regular measurement of individual car movements as a way to effectively compete with trucks (1). Landow, in particular, advocated the adaptation of a service reliability index to measure service performance and to allow adjustments for tariffs to reflect the costs of inventory for the customer in light of poor reliability.

While not specifically advocating statistical process control (SPC) charting techniques, a 1974 Harvard Business School case (2) listed the primary causes of delay to individual freight car movements, as well as the problems encountered in the operation of a classification yard. This study listed a number of potential solutions, such as more frequent and shorter train movements, but did not seek to improve the process of freight car classification itself.

Mundy et al. (3) noted the importance of service industries adopting SPC techniques, including control charts, Pareto analyses, and histograms. They cited the example of a limousine company for which Pareto analysis was used to pinpoint reasons for service failures, including lateness, reservation errors, client failures, and uncontrollable factors.

Deming (4) suggested a number of potential applications for SPC techniques in the railroad industry. These applications include monitoring of transit times for freight car movements in specific corridors, reducing errors in interline settlements and local billing, decreasing idle time of freight cars, studying specific delays in transit times, studying time spent repairing freight cars by type of repair, elapsed time between a customer's call for an empty or the pickup of a load, probability sampling to determine sections of roadbed to be examined, and determining future needs for parts and general maintenance.

Although some companies, including Ford, Tennessee Eastman, and Holley Carburetor, use SPC to monitor their rail carrier performance, only recently have rail carriers begun to use SPC techniques to monitor their own freight car movements for continuous improvement.

The traditional approach toward measuring service levels in the railroad industry has been to monitor on-time train performance. Although this approach has relevance to terminal trainmasters and district superintendents, it has little, if any, meaning to the individual shippers. Unless they are using dedicated unit trains, shippers are concerned only with whether shipments are on their sidings or team tracks when needed.

The first comprehensive study to examine the issue of reliability (as compared with on-time performance) was conducted at the Massachusetts Institute of Technology in 1972 (5) under a contract from FRA. Researchers studied service levels on several different railroads and analyzed in-depth the operations on the Southern Railway. They concluded that the greatest barrier to reliable operation was in the classification yards. The authors not only suggested making reliability a chief corporate goal, but also listed a series of intermediate steps that could be undertaken to bring it about. These steps included the following.

1. Provide sufficient motive power at terminals to avoid yard and road delays.
2. Increase the number of run-through trains to avoid blocking at intermediate yards.

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3. Adjust train schedules to reflect actual, not ideal, performance.
4. Allow sufficient time at yards for cars to make important connections without excessively disrupting yard operations or delaying outbound trains.
5. Limit the number of train and block cancellations to emergencies requiring management approval.

Although a number of trucking companies have successfully marketed their ability to facilitate just-in-time deliveries, it has only been in the past several years that railroad companies have shown an interest in going after this type of traffic. Some railroad companies are now developing corresponding SPC techniques (primarily \bar{X} -bar and R charts) to monitor and guide their efforts for specialized service, such as intermodal and some automotive trains.

Based on interviews with shippers (6), those who (still) use rail services are as much, if not more, concerned with consistency as they are with origin to destination delivery times. Thus, if railroads are to compete for traffic they must continually improve reliability and consistency while lowering unit costs. Just as SPC techniques have permitted manufacturing organizations to do this, so may they for transportation service industries including railroad operations. Although the use of SPCs will not directly bring about improved transit times and consistency, it will allow carriers to pinpoint areas for improvement and give clear direction to the improvement efforts.

INTRODUCTION TO SPC AND ITS IMPLICATIONS

Before the discussion of the application of SPC techniques at railroad classification yards, it should be clarified what SPC is and what it is not. Basically, SPC is a management tool. It is not a miracle cure or a panacea.

SPC is generally taught as one part of a larger overall management philosophy, the same philosophy that spawned such concepts as just-in-time, quality circles, participative management, and continuous improvement. It can be adopted alone, by an individual manager or to solve individual problems, but without a change in overall corporate management style its potential and effectiveness will be extremely limited. This is because SPC does not solve problems. Instead it provides clues as to what causes problems and requires a management team that is committed to the philosophy of continuous, gradual improvement.

To make constructive use of SPC data, one must first understand the basic statistical principles behind it.

Measurement

To use statistics, one must have both something to measure and a means of measurement. The something should be thought of as the output of a process. In manufacturing, units coming off a production line are measured for conformance to specifications or standards. In a service industry, one may not have a physical good to measure, but one will have a service produced by some sort of process, with some set of defined specifications for that service.

In manufacturing, measurement of output is usually in terms of physical description, such as size, weight, thickness, or color. These types of measurements produce a continuous distribution. When measuring the production of a service (e.g., the delivery of a package from point A to point B), one may use either continuous or binary (yes or no) distributions. The time elapsed between pickup and delivery would be a continuous variable, whereas the occurrence of a loss or damage would be binary. Often, it is most appropriate, or at least easiest, to test a service product against a preset standard of success, resulting in a binary success or fail variable.

Variation

In any statistical population sampled, variation will exist. Expressed more simply, "No two things are alike. They will always vary," (7, p. 1). Deming describes two types of causes of variation: common causes and special causes.

Common causes can be thought of in terms of variation due to chance. These are the causes of variation in the results of an experiment performed over and over under identical conditions, such as rolling a die. They arise out of the process or out of the way the process is organized and operated.

Special causes are sources of variation that do not belong to the system. Often they will be specific to a certain operator, machine, or batch of material. In the die-rolling experiment, by occasionally substituting a chipped die for the regular one, a special cause of variation has been introduced.

Note that whereas a continuous variable measurement, such as elapsed time, can capture the subtle difference from one product to another, a binary measurement cannot. If one records a failure, one does not have a record of the amount of variation present. This is why continuous measurement is generally preferred whenever possible.

Four Areas of Statistics

The four areas of statistics are descriptive statistics, probability theory, statistical inference, and SPC (7, pp. 22–24).

Descriptive statistics involve the summarizing of information contained in a data set. This includes basic measurements of a population, such as the mean, median, and standard deviation.

Probability theory is the mathematical modeling of random phenomena. Generally, probability theory allows one to describe the future outcomes of a system that is completely known, even though individual outcomes are random.

Statistical inference involves an attempt to infer the properties of an unknown population based on a randomly drawn sample. Basically, the goal is to determine whether the sample drawn is representative of the total population.

SPC involves an attempt to determine whether a series of data sets came from the same population, or resulted from the same process. If it did, statistical inference can be used to draw conclusions about the underlying population, such as a prediction of variance in future output. If not, then the questions of inference are moot.

The application of SPC in industry, therefore, allows determination of whether the output, or thing being measured, is the result of a single, identical process. Given that there

will be variation in the output, SPC allows determination of whether variation results entirely from common causes (factors within the system), or from special causes (factors outside the system). If variation is shown to be entirely from common causes, the process is said to be in control.

Many managers, after applying SPC and learning that their process is in control (a bit of often misunderstood SPC jargon), smile, pat themselves on the back for doing a good job, and go no further. They fail to understand that SPC does not pass judgment on their process. It simply shows how much variation to expect in output, given that the process is left to operate the same way each day, with no unusual or outside factors influencing it. It is up to the individual or the firm (and ultimately, the customer or end user of the output) to determine whether the level of variation inherent in the process is acceptable. The value of having a process in control, that is, with all variation in output being due to the system or process itself, is that it allows the manager to detect the causes of variation within the process and eliminate them. By watching the control charts, the manager can determine whether changes made in the system, such as a new track layout, more frequent locomotive maintenance, or a change in switching schedules, have truly changed the system's capabilities and whether the change is for the better. Likewise, if a process that has been operating in control with no changes enacted begins to send out-of-control signals, the manager receives early warning that a special cause has crept in and changed the process.

Philosophy Behind SPC

Deming's much-talked-about management philosophy, which revolutionized Japan's post-World War II economy, is based on the idea that variation, while inevitable, is the root of all evil. Deming argued that reducing variation leads to lower cost and increased productivity, regardless of whether existing variation conforms to a set of expectations or standards. Furthermore, he contended that the notion that quality and cost are incompatible and represent a trade-off is completely wrong. By reducing variation, quality and productivity go up, and cost goes down (4, p. 3).

Another significant argument of Deming's is that only a fraction of the total variation in output can be corrected by workers doing their best. By working harder and studying their own work for causes of mistakes, workers can only remove about 15 percent of the variation within the system.

The remaining 85 percent of the variation is caused by the system factors put in place and controlled directly by management, such as equipment or standard operating procedures. (Recently Deming suggested that this ratio may actually be 5 percent labor to 95 percent management.)

It is the observation of this principle in practice that has led early SPC practitioners such as Deming, Juran, and others to a new management philosophy. This philosophy is essentially the same as that of the Japanese, whose approach actually springs from their application of SPC methods on a widespread basis in the early 1950s.

Vaughn Beals, chairman and chief executive officer of Harley-Davidson, studied his Japanese competitors thoroughly and concluded, "It is not robotics or automation that gives them their competitive edge. It is not substandard wages. It is not

culture. And, it is not the morning calisthenics and company songs. What it is, is management—no more, no less," (8, p. 9).

Therefore, although SPC is only a management tool, it is a tool whose effectiveness is greatly related to the management philosophy of the user. Companies that have attempted to adopt it in isolation, just as with those that have tried to utilize just-in-time or quality circles without adapting the organization to fit the new methods, have had limited success. These implications regarding management philosophy and corporate culture for railroads are beyond the scope of this paper, but should be taken into consideration.

DESCRIPTION OF RESEARCH STUDY AND OPERATIONS AT TENNESSEE YARD

The Burlington Northern's (BN's) Tennessee Yard facility in Memphis (built for the St. Louis-San Francisco Railway Company, which was merged into BN in 1980) is the newest and largest railroad classification yard in the Memphis area. It was built in 1959, and is the only hump or gravity yard in the Memphis area.

The Tennessee Yard was designed to classify up to 2,400 cars on 61 tracks. Ten of these tracks have since been removed to make way for a trailer-on-flat-car facility, and current managers believe the yard could work efficiently handling up to 2,000 cars daily. During the initial phase of the University of Tennessee study from August to the first part of December 1987, the yard handled from 7,778 to 9,730 cars weekly and 596 to 1,817 daily. The average number of cars handled daily is between 1,260 and 1,300, with 5:00 a.m. being the busiest and 2:00 p.m. being the least busy. With the exception of Expediter trains (BN's scheduled, time-sensitive intermodal trains) and through unit coal and grain trains, all trains arriving at Tennessee Yard are broken up and reclassified. Sixteen arrivals and departures daily were scheduled.

The present set of standards calls for through trains to be reclassified and on their way within 8 hr. Cars bound to or from local industries within the Memphis Terminal area are to be placed locally or placed on a through train within 24 hr of their pickup. Cars being sent to connecting railroads are to be moved within 14 hr.

DATA COLLECTED

Managers at Tennessee Yard used a daily terminal performance report, (the TPC report), generated by BN's central information service. This report contained a variety of detailed information on car movements through the terminal. Three sections of the report were used to collect data for SPC analysis.

Daily Cars Over Standard Report

This section of the TPC report provided detailed information on each car within specific movement groups that left the terminal in more than standard time during the day. An example of this report is shown in Table 1.

TABLE 1 DAILY CARS OVER STANDARD REPORT (C-1 SUNDAY, SEPTEMBER 20, 1987)

Exhibit A														
DAILY CARS OVER STANDARD REPORT								C-1 SUNDAY		SEPTEMBER 20, 1987				
CAR	L	CR	CON-	DEST.		ARRIVED-RELEASED			STANDARD GOAL		DEPARTURE-PLACED		HRS	
UNIT & NRR	E	KD	TENTS	JCT	TAG	MODYHR	TRB/RD/ETC		MODYHR	TRN/RD/ETC	MODYHR	TRN/RD/ETC	OVR	
TRAIN ARR/MH - THRU CRS/120														
HTTX	98887	L	FE	MACHRY	BIMICS	328	092005	01120	15	092010	120	092012	95636	2
HTTX	98447	L	FE	MACHRY	BIMICS	328	092005	01120	15	092010	120	092012	95636	2
13 TOTAL CARS. 15% OVER STANDARD. \$2														
TRAIN ARR/MH - THRU CRS/101														
TGAX	131425	L	TS C	ACID	20712	536	091823	01181	18	091905	181	091913	01793	8
TGAX	131362	L	TS C	ACID	20712	536	091823	01181	18	091905	181	091913	01793	8
26 TOTAL CARS. 7% OVER STANDARD. \$9														
INDUSTRY/MH - NORTHTOWN/MH														
BNFE	19306	E	R7	836001	00673	966	091814	RLSE	132801	091910	143	092007	01143	20
OTTX	90442	E	FE	830	01600	966	091814*	RLSE	120210	091910	143	092007	01143	20
OTTX	90394	E	FE	840	01600	966	091815*	RLSE	120210	091910	143	092007	01143	20
BN	630485	E	FE	830100	01600	966	091815*	RLSE	120210	091910	143	092007	01143	20
4 TOTAL CARS. 100% OVER STANDARD. \$49														
TRAIN ARR/MH - GALESBURG/MH														
MILW	4416	E	A5	8488222	CHIBR	716	091901	01792TU	18	091910	143	091918	01247	7
16 TOTAL CARS. 6% OVER STANDARD. \$4														
INDUSTRY/MH - GALESBURG/MH														
USLX	13135	E	R5	838	CHICR	716	091814	RLSE	063404	091910	143	092007	01143	20
CNW	172216	E	C6	856	RISCI	716	091816	RLSE	142020	091910	143	092007	01143	20
GTW	598346	E	XF	838222	CHIGT	716	091816	RLSE	131599	091910	143	092007	01143	20
7 TOTAL CARS. 42% OVER STANDARD. \$37														
TRAIN ARR/MH - NE SHORTS/MH														
MP	650327	L	GS	STLBAR	98237	220	091809	01120	13	091910	143	091918	01247	7
BN	457292	E	C6	856001	98237	220	091819	95635	18	091910	143	091918	01247	7
BN	456422	E	C6	856001	98237	220	091819	95635	18	091910	143	091918	01247	7
ATSF	350004	E	C5	854	98131	210	091823	01181	18	091910	143	091918	01247	7
BN	448847	E	C6	856001	98045	200	091823	01181	18	091910	143	091918	01247	7
BN	455837	E	C6	856001	98045	200	091823	01181	18	091910	143	091918	01247	7
ATSF	350133	E	C5	853	98131	210	091823	01181	18	091910	143	091918	01247	7
BN	454841	E	C6	856001	98237	220	091823	01181	18	091910	143	091918	01247	7
BN	390158	E	A6	848112	98237	220	091823	01181	18	091910	143	091918	01247	7
BN	455785	E	C4	856001	98237	220	091823	01181	18	091910	143	091918	01247	7
BN	437230	E	C5	854007	98037	200	091823	01181	18	091910	143	091918	01247	7
BN	419259	E	C5	853007	98037	200	091823	01181	18	091910	143	091918	01247	7
BN	418578	E	C6	856001	98045	200	091823	01181	18	091910	143	091918	01247	7
BN	450828	E	C6	856001	98045	200	091823	01181	18	091910	143	091918	01247	7

The first two cars listed, HTTX 93887 and 93447, were part of a movement group of 13 through cars on Train 120. These particular cars were loaded with machinery bound for Birmingham. They arrived at Tennessee Yard on September 20 at 0500 hr and, according to standards, were to be released the same day on the same train at 1000 hr. They were actually released at 1200 hr on Train 95636, 2 hr over standard.

The next two cars have a similar story. They were among 26 cars scheduled to pass through the terminal on Train 181; however, they were delayed and sent out on Train 793, 8 hr over standard.

Daily Group Performance

The daily group performance report shows all the activity in the yard by movement group. In Table 2, the first two movement groups listed are through cars for Trains 120 and 181. In each case, two cars out of the total group were over standard—in the first case by 2 hr each, in the second by 8 hr each.

The report has separate columns for cars that were less than or more than 24 hr over standard, as well as a total column.

In addition to showing the percentage of the movement group over standard, the report provides a theoretical cost in dollars of the failure to meet standards.

Note that whereas the daily cars over standard report only shows cars exceeding standards, the group performance report provides information on all cars moving through the terminal. For example, the fifth group listed shows that all 24 cars received in interchange from the Southern and scheduled to leave on Train 073 made the connection and were within standard.

Daily Terminal Performance Summary

This report, shown in Table 3, provides a summary of daily performance during a 4-week period. For example, on September 20, 749 cars were in the terminal, requiring 1,270 car movements. The report provides a good deal of cost and productivity measurements, such as car movements per engine hour, but in terms of monitoring variation and process capability, the most useful figure is the total over standard, which was 12 percent on September 20.

TABLE 2 WEEKLY GROUP PERFORMANCE AT MEMPHIS TERMINAL (B2: SEPTEMBER 14-20, 1987)

MOVEMENT GROUP	TOTAL MVMNTS	TOTAL CAR HOURS	CAR HOURS PER MVT	CARS OVER STD	HOURS OVER STD	0-24 OVER PCT	HRS STD DLRS	GR 24 OVER PCT	STD DLRS	OVER PCT	STD DLRS
TRAIN ARR/MH-THRU CRS/120	116	739	6.3	3	27	2	\$17			2	\$17
TRAIN ARR/MH-THRU CRS/181	208	1579	7.5	5	110	1	\$40		\$29	2	\$68
TRAIN ARR/MH-CONN 021/143	15	53	3.5								
TRAIN ARR/MH-CONN 021/181	13	21	1.6								
I/C RECD /MH-CONN SOU/073	114	541	4.7	2	54		\$ 9		\$24	1	\$33
EXPEDITER/MH-EXPEDITER/MH	31	104	3.3								
TRAIN ARR/MH-EXPEDITER/MH	31	97	3.1								
TCF RAMP /MH-EXPEDITER/MH	223	606	2.7								
TRAIN APR/MH-NORTHTOWN/MH	82	1399	17.0	12	105	14	\$65			14	\$65
I/C RECD /MH-NORTHTOWN/MH	105	1479	14.0	2	3	1	\$2			1	\$2
TCF RAMP /MH-NORTHTOWN/MH	1	12	12.5								
INDUSTRY /MH-NORTHTOWN/MH	7	288	41.1	7	143	100	\$89			100	\$89
OTHER /MH-NORTHTOWN/MH	5	68	13.7								
TRAIN ARR/MH-GALESBURG/MH	150	1890	12.6	6	69	49	\$43			4	\$43
I/C RECD /PI-GALESBURG/MH	1	20	20.0								
I/C RECD /MH-GALESBURG/MH	28	374	13.3								
AUTO RAMP/MH-GALESBURG/MH	9	146	16.3								
INDUSTRY /MH-GALESBURG/MH	57	1801	31.6	26	441	45	\$273			45	\$273
OTHER /MH-GALESBURG/MH	16	316	19.7								
TRAIN ARR/MH-ST. LOUIS/MH	186	2574	13.8	39	362	20	\$204		\$ 20	20	\$224
I/C RECD /MH-ST. LOUIS/MH	45	906	20.1	10	75	22	\$47			22	\$47
AUTO RAMP/YA-ST. LOUIS/MH	2	88	44.4	2	42	100	\$26			100	\$26
AUTO RAMP/MH-ST. LOUIS/MH	34	694	20.4	7	63	20	\$39			20	\$39
INDUSTRY /MH-ST. LOUIS/MH	13	402	30.9	9	166	61	\$74	7	\$ 29	69	\$103
OTHER /MH-ST. LOUIS/MH	4	69	17.3								
TRAIN ARR/MH-NE SHORTS/MH	118	2171	18.4	63	483	53	\$299			53	\$299
I/C RECD /MH-NE SHORTS/MH	41	883	21.5	25	188	60	\$117			60	\$117

TABLE 3 DAILY TERMINAL PERFORMANCE (A-1 SUNDAY, SEPTEMBER 20, 1987)

DATE	CARS IN TERM.	TOTAL CAR MVMNTS	ENGINE HOURS ST	ENGINE HOURS QT	CAR MVMNTS PER ENG HOUR	C & E COST PER MVT	CAR DAY COST PER MVT	TOTAL COST PER MVT	TOTAL OVER STANDARD FRONT	TOTAL DOLLARS
09-20	749	1270	96			\$ 6.34	\$0.03	\$14.37	12%	\$1191
09-19	1085	1523	80			\$ 4.40	\$6.95	\$11.36	9%	\$ 964
09-18	1097	1409	128			\$ 7.63	\$6.73	\$14.36	9%	\$ 775
09-17	1161	1445	128		11.29	\$ 7.44	\$8.15	\$15.59	16%	\$1754
09-16	1145	1195	136	1	8.72	\$ 9.65	\$7.03	\$16.68	9%	\$ 919
09-15	1047	1186	128		9.27	\$ 9.07	\$6.60	\$15.67	12%	\$ 947
09-14	750	1156	128	2	8.89	\$ 9.49	\$7.62	\$17.11	12%	\$ 590
	1006	9184	520	3	17.56	\$ 4.79	\$7.30	\$14.87	11%	\$7148
09-13	734	1049	104		10.09	\$ 8.33	\$9.03	\$17.36	15%	\$ 944
09-12	836	1404	80		17.55	\$ 4.79	\$9.11	\$13.90	18%	\$1749
09-11	1138	1360	128	2	10.46	\$ 8.07	\$8.92	\$16.99	19%	\$1326
09-10	1127	1245	128	1	9.65	\$ 8.72	\$8.17	\$16.89	13%	\$ 892
09-09	1153	1132	128	1	8.78	\$ 9.59	\$7.68	\$17.27	17%	\$1361
09-08	1013	904	128	3	6.90	\$12.25	\$7.35	\$19.60	10%	\$ 979
09-07	743	969	48		20.19	\$ 4.16	\$8.87	\$13.03	12%	\$ 767
	963	8063	744	7	10.73	\$ 7.84	\$8.49	\$16.33	15%	\$8017
09-06	950	1331	96	1	13.72	\$ 6.14	\$9.01	\$15.15	14%	\$1182
09-05	1154	1436	80		17.95	\$ 4.68	\$7.41	\$12.09	13%	\$ 702
09-04	1092	1378	128	1	10.68	\$ 7.88	\$8.81	\$16.69	15%	\$1790
09-03	1207	1321	128		10.32	\$ 8.14	\$8.77	\$16.91	17%	\$1510
09-02	1154	1536	128	2	11.82	\$ 7.14	\$8.17	\$15.31	15%	\$1363
09-01	1523	1132	128	1	8.78	\$ 9.59	\$6.32	\$15.91	7%	\$ 508
08-31	977	984	128	1	7.63	\$11.04	\$8.27	\$19.31	12%	\$ 637
	1151	9118	816	6	11.09	\$ 7.58	\$8.13	\$15.71	13%	\$7692
08-30	902	1394	96		14.52	\$ 5.78	\$6.39	\$12.17	4%	\$ 482
08-29	1340	1605	88		18.24	\$ 4.61	\$8.12	\$12.73	11%	\$1041
08-28	1401	1343	128	1	10.41	\$ 8.09	\$7.49	\$15.58	11%	\$ 662
08-27	1243	1154	128	1	8.95	\$ 9.41	\$8.54	\$17.95	17%	\$1084

STANDARDS OF MEASUREMENT

Each terminal has had its own performance standards developed. These unique standards were built into the TPC report. Basic standards for the Memphis terminal, as outlined earlier, are 8 hr for through movements and 24 hr for local origin/destination traffic.

It is important to note that failure to meet these standards does not always reflect a failure to perform by the terminal. For example, cars on an outbound train cannot be released until the train actually leaves the yard. However, trains may be delayed or even cancelled due to problems outside the terminal's control, such as a derailment on the mainline or a power shortage. In such cases, all affected cars show up on the report as being over standard, even though the terminal has done its job and constructively placed these cars in an outbound consist within the standard time allotted.

Another example involves local industry. In order to gain maximum use of cars delivered to their siding while avoiding demurrage charges, some shippers have been known to release cars immediately after the switch crew has left the area. If the shipper is approaching the point at which demurrage will be charged, this tactic allows the shipper to avoid demurrage while retaining use of the cars until the next scheduled switch. To the terminal, this may mean that the car is released 23 hr before the next day's scheduled switch, making

it almost impossible to remain within standards without performing a special switch.

Thus, in looking at the Memphis terminal's performance, or any railroad terminal, the yardstick used for measurement must be kept in mind. The standard used in this case is based simply on the hours elapsed from the time of release to the terminal and time of release from the terminal. These times are influenced not only by the performance of the terminal operation itself, but also the actions of connecting railroads, shippers, and other BN operating groups. Under this standard of measurement, the only process that can be truly measured must be considered to include all of these parties. However, detailed analysis can identify where the causes of variance (i.e., service failure) occur.

A final point to note is that although one is working with a continuous variable (percentage over standard), this is based on a binary test to determine whether each car was or was not over standard. At this summary level, the number of hours over standard is not taken into account.

APPLICATION OF SPC

Flowcharting

The first step in applying SPC methods to the Memphis terminal was to flowchart the process to be studied. As discussed

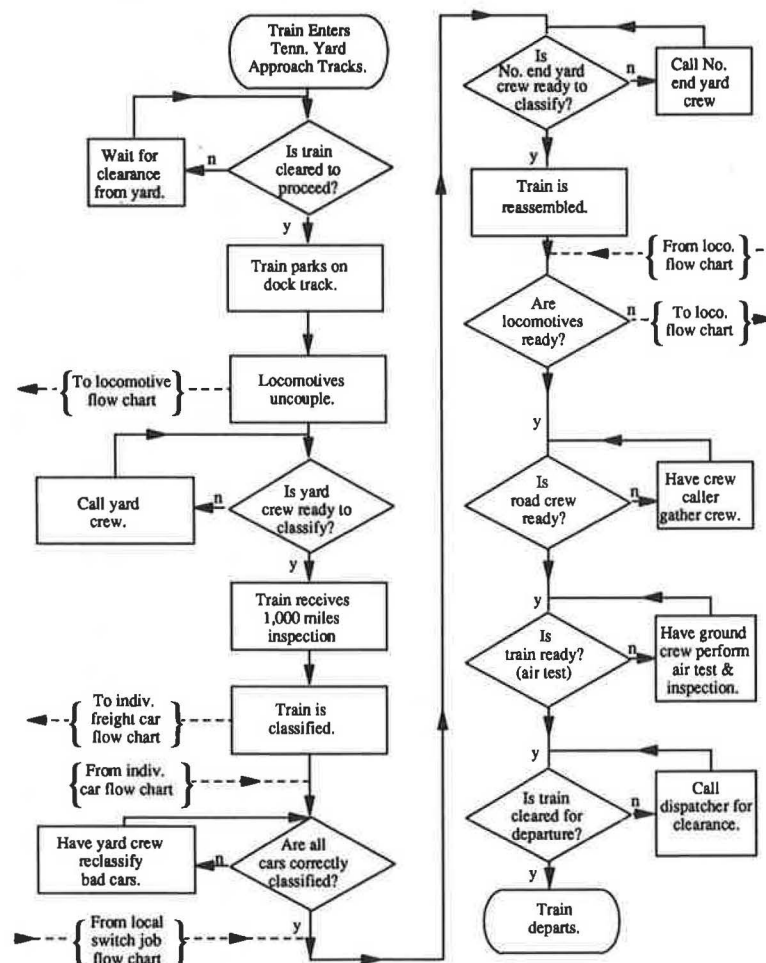


FIGURE 1 Train flow chart (BN Tennessee Yard, Memphis).

earlier, actual flowcharting was done on several subprocesses and not on the process as a whole. Example flowcharts can be found in Figures 1–3.

These flowcharts were prepared by the researchers from interviews with management and were intended primarily as a framework for further discussion and flowchart development by management. They were by no means complete. They were, however, a starting point for further work.

Accurate flowcharting is important to in-depth SPC analysis because it clarifies the boundaries of the process and provides information on points within the process at which to collect sample data. In this study, SPC analysis was performed on existing data because the collection of additional sample data was impractical given the limited scope of the project. However, a more serious long-term effort would require the collection of data at specific points as identified through flowcharting and other methods such as “fishbone” and Pareto analysis.

An important side effect of the flowcharting step is that it can be educational for managers. Asked to develop flowcharts individually, managers will usually not come up with identical versions. As they interact to create a flowchart, their understanding of the process is enhanced. Additional enlightenment is often obtained when line workers are involved in the process. It is common for managers to find that what is actually going on is different from what they think is going on. Also,

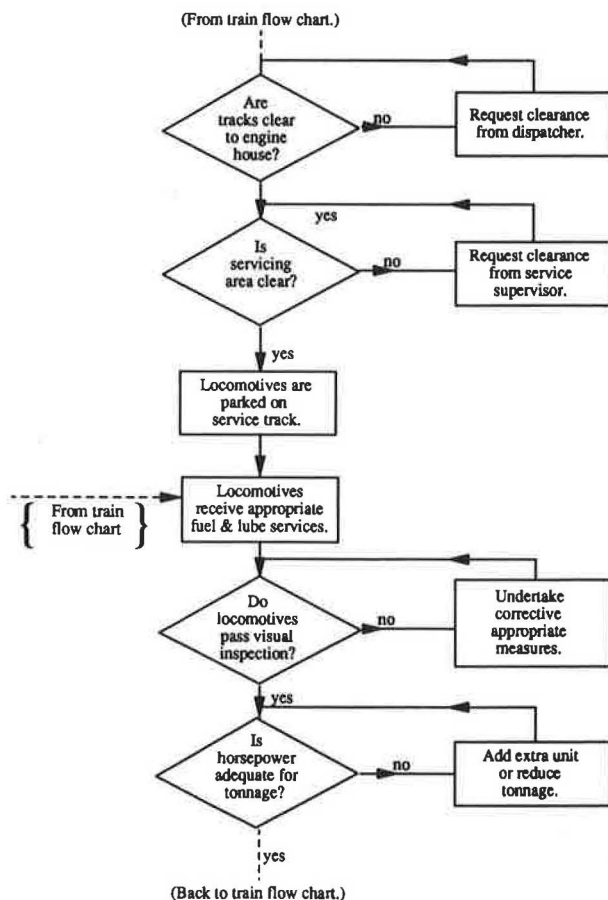


FIGURE 2 Locomotive flow chart (BN Tennessee Yard, Memphis).

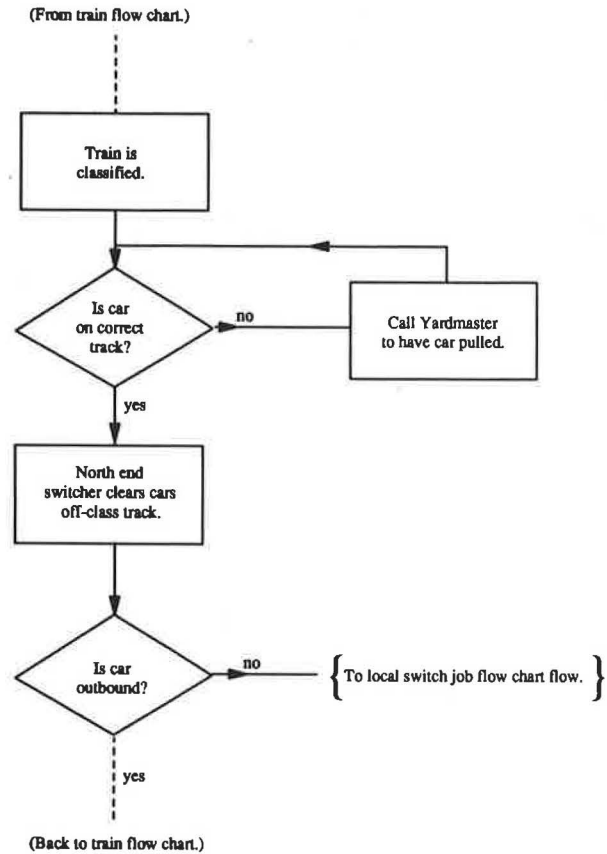


FIGURE 3 Individual freight car flow chart (BN Tennessee Yard, Memphis).

it may be found that different shifts or work groups are performing the same work through different processes.

In manufacturing, flowcharts identify the points at which inspections are performed on the product, which may lead to acceptance or may destine it for rework or the scrap pile. The goal of reducing variation in the process is to eliminate this scrap or rework and ultimately even the inspection process itself, thereby reducing costs. Data are collected and analyzed at these points in order to determine the causes of variation.

Such decision points in the process are represented by diamond-shaped boxes. Square boxes represent production steps or activities. In the flowcharts presented here, the diamonds contain variables that are decisions in the sense that they may or may not result in rejection of the service performed (meaning that standards were not met).

For example, if a car is found to be incorrectly humped (placed on the wrong track), rework must be performed—a switcher must be sent in to correct the error. The resulting delay may also cause the car to exceed standard time. If management wants to eliminate incorrect humping, it must collect and analyze data at this point in the process to determine the causes of variation present.

Control Charts

As a first step in analyzing the Memphis terminal operation, control charts were created on the basis of aggregate perfor-

mance data provided in the TPC report. These charts track the weekly average performance of all movements through the terminal (including Expediter trains).

Specifically, the daily percentage of cars over standard, as reported in the daily terminal performance summary, was collected for the period July 24 through November 30. Each day's performance was treated as a single observation in a weekly sample. The *R* chart in Figure 4 charts the weekly range of the observations. The average range between the high and low observation is .117 (i.e., the average variation is 11.7 percentage points). The upper control limit is .226, and the lower control limit is .009. This means that a weekly range of more than 22.6 or less than 0.9 percentage points indicates that the process is out of control—that a special cause has entered. Variation within these limits is due to the process itself and can be expected until the process is changed.

As can be seen from the chart, the process is indeed out of control with respect to range for the week beginning October 13. On the 15th, a bridge fire closed the mainline for several hours, backing up traffic and delaying the departure of outbound trains in the yard. On that day, 29 percent of the cars in the yard exceeded standard. Four days later, only 5 percent exceeded standard, leading to a range of 24 percentage points. Whereas other observations showed performance levels at 6, 5, and even 4 percent, the highest observation excluding the 15th was 26 percent, indicating that the October 15 observation was the outlier signaling a special cause.

The *X*-bar chart plots weekly averages. Average weekly performance was 13.9 percent over standard, with control limits at 18.8 and 9 percent. As can be seen, the *X*-bar chart remains in control, indicating a single process in operation.

File:	BN1
Company:	Univ. of Tennessee
Plant:	Burlington Northern R.R.
Department:	Memphis Terminal
Machine:	TN Yard
Operation:	Class., Switch
Characteristic:	Weekly cars over standard
Sample frequency:	1 week
Units:	% of total

1	.12	.13	.11	.14	.08	.07	.10	.12	.13	.10	.10	.15	.06	.15	.11	.13	.08	.11
2	.09	.16	.17	.06	.13	.15	.17	.09	.15	.16	.12	.15	.12	.16	.14	.11	.17	.12
3	.14	.22	.20	.17	.17	.17	.13	.16	.17	.16	.19	.29	.17	.24	.16	.18	.26	.23
4	.13	.12	.21	.15	.11	.15	.19	.09	.17	.20	.20	.17	.21	.14	.13	.18	.15	.21
5	.08	.16	.07	.17	.11	.13	.18	.10	.15	.14	.21	.18	.11	.12	.10	.17	.17	.12
6	.12	.06	.14	.12	.04	.14	.15	.12	.13	.09	.22	.17	.11	.15	.08	.09	.12	.05
7	.20	.11	.10	.12	.12	.12	.12	.12	.12	.19	.15	.05	.17	.15	.13	.09	.09	.06

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
X-Bars:	.126	.137	.143	.133	.109	.133	.149	.114	.146	.149	.170	.166	.136	.159	.121	.136	.149	.129
Ranges:	.120	.160	.140	.110	.130	.100	.090	.070	.050	.110	.120	.240	.150	.120	.080	.090	.180	.180

X-BAR CHART

LCL = .09 MEAN = .139 UCL = .188

USING HISTORICAL LIMITS, BASED ON 0728 to 1117

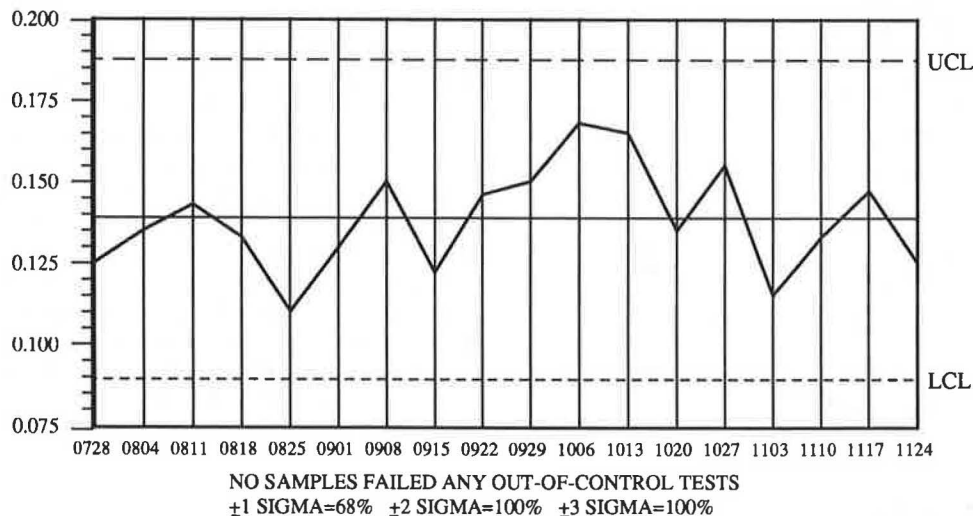


FIGURE 4 Weekly cars over standard.

The observation for the week of October 13, however, is theoretically in control only by chance, because the range chart shows it to be the result of a different process with unknown average and control limits.

One of the important things about the \bar{X} -bar chart is that it shows clearly the process capability and the variation that can be expected from week to week. The Memphis terminal, when measured against the existing standards, will always have somewhere between 9 and 19 percent of cars over standard. Furthermore, it is known that the average is 14 percent, and that there will always be some weeks above and some below the average. Finally, unless the process is changed, performance better than 9 percent over standard in a given week cannot be expected.

Such information is useful. The size and scope of the process should be considered, including all activities or subprocesses in the terminal. Expediter trains ought to do much better than the overall process, and in fact should be expected to pull the average down. They are really a separate process. Likewise, connecting railroads and shippers' actions are included in this process. It is obvious that interchange, local industry service, and through-train classification are different processes.

Another factor is the cyclical nature of traffic within the week. According to management, and as shown in the daily terminal performance summary, traffic through the terminal is heavier Wednesday through Saturday than Sunday through Tuesday.

Another approach to charting performance on \bar{X} -bar and R charts is to treat each day's percent over standard as an individual sample of one, with the range being the difference between the day being charted and the previous day. When the data were calculated in this method, the resulting charts failed out-of-control tests at several points, and a cyclical pattern was evident. This suggests that each day is actually a subprocess that could be analyzed and improved.

Pareto Analysis

The third SPC technique applied was Pareto analysis—the simple assignment of causes to failures, or cars over standard. For this analysis, management tracked down and recorded the causes of delay for all cars more than 24 hr over standard during the month of November, using the daily cars over standard report. The results are shown in Figure 5.

This analysis provides guidance in allocating time and effort to improve performance. Three of the 13 causes discovered were responsible for more than half the service failures. Clearly, management will want to know more about the reporting errors leading to cars missing standard. Are these errors causing actual delays to cars, or are they simply failures on paper? An example is failing to release a car sent to the rip track for repairs.

Such results are typical, however, of a first iteration of the Pareto chart principle. Usually, reporting and other data collection techniques must be refined in order to capture more of the story. In examining reporting errors, it is expected that several causes for these errors will be identified. The reporting process then, is a subprocess, which can be subjected to continued Pareto analysis, control charting, and the like to determine its capabilities or whether changes made have produced a better process.

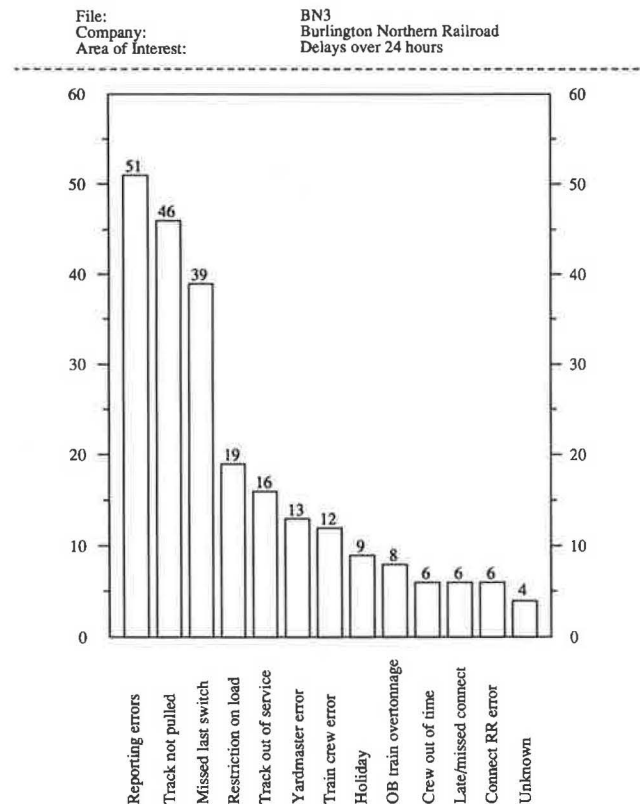


FIGURE 5 Delays longer than 24 hr.

IMPLICATIONS FOR MANAGEMENT

In manufacturing, control charts are traditionally generated using information taken from samples of a larger population, and the sampling procedure used is critical to the interpretation of the charts. In this application, the sample is all-inclusive, but, as noted in the discussion on control charting, this population is really the result of several subprocesses and in fact consists of several products. Thus, the composition of our sample is critical to interpretation of the results.

Figure 6 graphically depicts the sampling procedure. The data utilized to generate control charts are the aggregate of several different types of products produced on different days of the week, which have been identified as being separate processes. There are many different ways to collect and analyze data (or sample), depending on which process or product managers want to know more about.

For example, one could sample weekly aggregate data for just one product line, such as trailer on flatcar service or interchange service. One could go further down the line by sampling just a particular product provided to one customer, such as interchange service with one connecting railroad. Total performance by day of week, or by product by day of week could be charted. One could even track inputs from suppliers, such as cars released by local industry. Note however that the boxes representing separate daily processes are really a composition of numerous subprocesses such as data entry and track maintenance, each of which could be monitored independently.

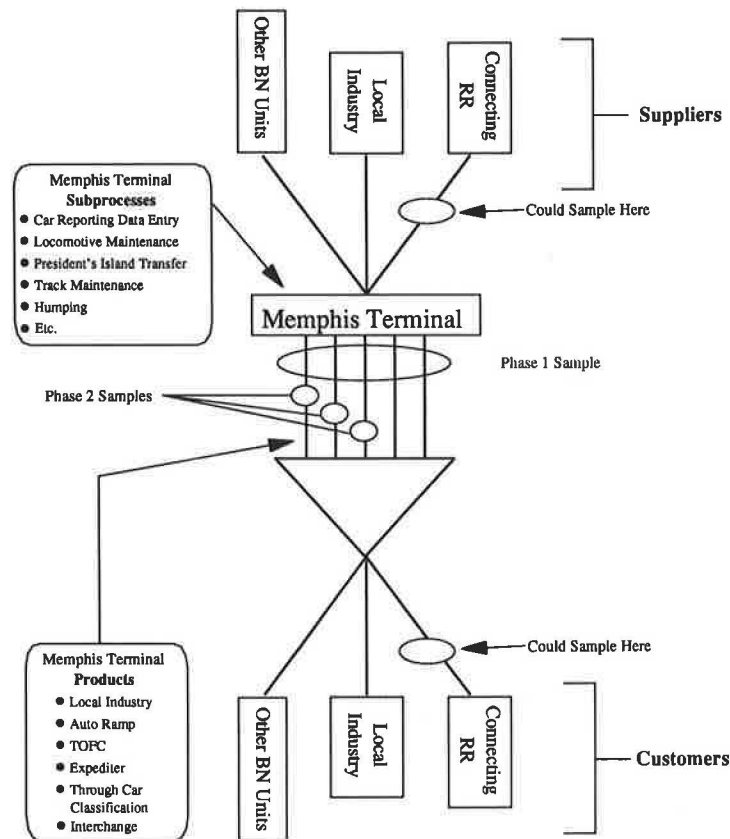


FIGURE 6 Sampling procedure.

The existing data reporting techniques used by most railroads, such as the TPC report, provide sufficient data for some of the suggested sampling techniques; however, other sampling plans would require new and different data collection and reporting. Clearly, it is not feasible to begin charting in all possible ways all at once. It is the task of management, through the use of flowcharting and Pareto analysis, to determine problem areas or possible areas for improvement, and to concentrate on those areas first. Sweeping, systemwide changes may bring in as many new problems as improvements: Deming vigorously argued that continual, incremental improvement and refinement of the process is the true path to superior productivity and quality.

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