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RESEARCH ARTICLE

Methods to Setup Process Adjustment Cost and Computational Efforts for Quality Control in Manufacturing

S. Y Gajjal[1] and Dr. A. P. S Gaur[3]

1. Associate Professor, NBNSSOE, Pune.
2. Professsor & Head, B.I.E.T, Jhansi.

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Abstract

Process adjustment setup problem was first studied by Grubb's. Process adjustment, Includes Grubb's harmonic and extended rules, adjustments method based on stochastic approximation and recursive least square, and a recent method on adaptive EWMA feedback controller. Feedback control methods have been proposed in recent literature to regulate the quality characteristic of parts or pro ducts in a manufacturing process. Depending on the costs involve d, adjustments may not be needed at each time instant. This paper presents scheduling methods to determine the optimal time instants for adjusting a process. The focus is on the setup adjustment problem, in which it is necessary to adjust in order to compensate for an initial offset that occurs due to an incorrect setup operation. The performance of three scheduling methods are compared in term s of the expected manufacturing cost and computational effort of each method. The adjustment methods considered are based on estimates of the process variance and the size of the offset.

Introduction

A setup error refers to a machine offset that occurs during the startup or maintenance operations. This error or offset may result in quality problems for the whole lot of parts produced after setting up the machine. Although a setup error can be speculated from observing an off-target value of the quality characteristic soon after starting production, the setup error cannot be measured directly due to the inherent variation in the process. In this paper, a sequential adjustment method that uses the sample average value of quality measurements over time to estimate the magnitude of the setup error is presented. A question addressed in this paper is to determine when to adjust using this method. We compare several methods for selecting an optimal or close-to-optimal adjustment schedule and provide some practical recommendations for setup adjustment in a short-run manufacturing process. By a sequential adjustment rule we w ill imply a procedure by which an operator makes successive adjustments to a machine. One adjustment is made every time a part is produced, and this can continue for several parts. As discussed below, some parts or time instants may go unadjusted, i.e., it might be benifical to skip some adjustments in the sequence.

In this paper, a special sequential adjustment strategy is described in which adjustments are scheduled to be carried out at some particular points in time along the time span of the manufacturing process . The cost function associated with the deviations from target will be assumed quadratic, and the adjustment cost will b e assumed to be fixed. In the following sections, we first introduce a sample-average adjustment procedure, and show its equivalency to Grubbs' extended rule. Three scheduling methods for sample-average adjustments are then presented. Their performance and robustness on a short- run manufacturing process is studied numerically. Finally, some recommendations and conclusions about the different scheduling adjustment methods are provided.

Algorithm for Process adjustment:

The sample-average adjustment procedure provides the opportunity of avoiding adjustment actions between two arbitrary adjusting times. This is especially useful when there are large fixed adjustment costs independent of the magnitude of the adjustments. In this section, we wish to find the best adjustment epochs or time instants such that they minimize the total manufacturing cost which is assumed to include the following components:

1. Expected off-target quality cost, C_q. This is the expectation of the sum of a quadratic function of Y_t around its target,

$$C_q = \sum_{t=1}^{n} E[\Omega(Y_{t\,-}\ T)^2],$$

Where ' n' is the number of parts that need to be manufactured in the lot and 'Ω' is the quadratic cost per unit. There exists an opportunity for adjusting the controllable factor for each of the 'n' parts.

2. Adjustment Cost, $C_{a.}$ This is assumed to be fixed and independent of the magnitude of the adjustment,

$$C_a = M\ X\ (\textstyle\sum_{t=1}^{n}(\delta(t)\ ,$$

Where δ(t) equal to zero when no adjustment is schedule and is one otherwise.

3. Measurement Cost, $C_{m.}$ This is assumed to b e proportional to the number of adjustments, i.e.,

$$C_m = G \times m\ ,$$

where m is the time of the last adjustment. Obviously, when the last adjustment has been executed and no more adjustments are needed till the end of production, measurements on the following runs are not necessary

Table 1: Comparison of costs, time and adjustment schedules of three schedule design methods.

n	G	M	method	cost	time(sec.)	adjustment	n	G	M	method	cost	time(sec.)	adjustment
25	0	0.5	WW	30.82	0.0	1-8	120	0	0.5	WW	128.25	0.42	1-8-19-44
			SM	31.02	0.0	1-6-12				SM	128.42	0.0	1-6-11-19-34-59
			Trih	31.96	0.32	1-4-7-12				Trih	128.77	0.43	1-4-8-15-28-43-66
25	0	1	WW	32.92	0.0	1-8	120	0	1	WW	130.11	0.42	1-11-34
			SM	33.02	0.0	1-4-10				SM	130.92	0.12	1-5-11-24-50
			Trih	33.96	0.33	1-4-7-12				Trih	131.71	0.38	1-4-9-20-34-59
25	0	2	WW	34.32	0.0	1	120	0	2	WW	133.11	0.42	1-11-34
			SM	34.92	0.0	1-8				SM	134.31	0.0	1-6-16-41
			Trih	35.36	0.21	1-3-8				Trih	136.22	0.33	1-3-7-17-41
25	1	0.5	WW	32.92	0.06	1	120	1	0.5	WW	139.72	0.42	1-8
			SM	32.02	0.0	1				SM	139.98	0.0	1-4-8
			Trih	33.36	0.21	1-4				Trih	140.04	0.27	1-4-9
25	1	1	WW	32.92	0.0	1	120	1	1	WW	140.68	0.42	1-8
			SM	32.02	0.0	1				SM	140.68	0.0	1-8
			Trih	34.36	0.16	1-3				Trih	141.68	0.23	1-3-9
25	1	2	WW	33.92	0.0	1	120	1	2	WW	142.68	0.42	1-8
			SM	33.92	0.0	1				SM	142.68	0.0	1-8
			Trih	36.36	0.16	1-3				Trih	144.68	0.23	1-3-9
25	2	0.5	WW	32.32	0.06	1	120	2	0.5	WW	144.12	0.42	1-5
			SM	32.32	0.0	1				SM	144.12	0.0	1-5
			Trih	34.36	0.21	1-3				Trih	145.16	0.11	1-3-6-11

25	2	1	WW	32.62	0.0	1	120	2	1	WW	145.12	0.42	1-5
			SM	32.62	0.0	1				SM	145.12	0.0	1-5
			Trih	35.36	0.2	1-3				Trih	146.66	0.23	1-3-7
25	2	2	WW	33.92	0.0	1	120	2	2	WW	147.12	0.42	1-5
			SM	33.92	0.0	1				SM	147.12	0.0	1-5
			Trih	37.36	0.21	1-3				Trih	150.66	0.23	1-3-7
60	0	0.5	WW	62.34	0.1	1-8-21	550	0	0.5	WW	561.65	8.16	1-8-19-44-100-224
			SM	63.03	0.0	1-5-9-17-29				SM	562.12	0.10	1-6-11-19-34-558-100-171-30
			Trih	63.52	0.32	1-4-8-15-23-34				Trih	562.18	0.62	1-4-8-16-32-55-96-107-289
60	0	1	WW	64.35	0.1	1-8-21	550	0	1	WW	564.37	8.15	1-8-26-71-189
			SM	64.92	0.0	1-5-12-25				SM	565.20	0.10	1-6-14-30-61-124-250
			Trih	65.76	0.29	1-4-8-15-28				Trih	566.03	0.46	1-4-9-20-45-100-171-293
60	0	2	WW	66.54	0.1	1-12	550	0	2	WW	568.62	8.16	1-12-43-148
			SM	67.37	0.0	1-8-20				SM	570.80	0.09	1-5-14-35-85-207
			Trih	69.22	0.21	1-3-8-20				Trih	572.64	0.39	1-3-7-23-64-127
60	1	0.5	WW	69.16	0.1	1-5	550	1	0.5	WW	594.16	8.15	1-8-20
			SM	69.16	0.0	1-5				SM	594.29	0.07	1-6-11-20
			Trih	69.65	0.20	1-4-6				Trih	594.39	0.31	1-4-9-21
60	1	1	WW	70.16	0.1	1-5	550	1	1	WW	595.66	8.24	1-8-20
			SM	70.16	0.0	1-5				SM	596.37	0.07	1-4-9-20
			Trih	70.25	0.16	1-6				Trih	596.55	0.26	1-3-8-21
60	1	2	WW	71.25	0.1	1	550	1	2	WW	598.28	8.17	1-19
			SM	72.16	0.0	1-5				SM	598.66	0.06	1-8-19
			Trih	72.16	0.23	1-5				Trih	599.35	0.24	1-4-20
60	2	0.5	WW	69.77	0.11	1	550	2	0.5	WW	608.91	8.16	1-7-14
			SM	69.77	0.0	1				SM	609.21	0.08	1-4-8-14
			Trih	72.16	0.29	1-5				Trih	610.26	0.28	1-4-8-15
60	2	1	WW	70.16	0.1	1	550	2	1	WW	611.30	8.16	1-14
			SM	70.16	0.0	1				SM	611.41	0.08	1-6-14
			Trih	73.04	0.29	1-5				Trih	611.49	0.25	1-6-15
60	2	2	WW	71.25	0.1	1	550	2	2	WW	613.30	8.15	1-14
			SM	71.25	0.0	1				SM	613.49	0.07	1-5-14
			Trih	74.37	0.16	1-4				Trih	613.80	0.23	1-4-15

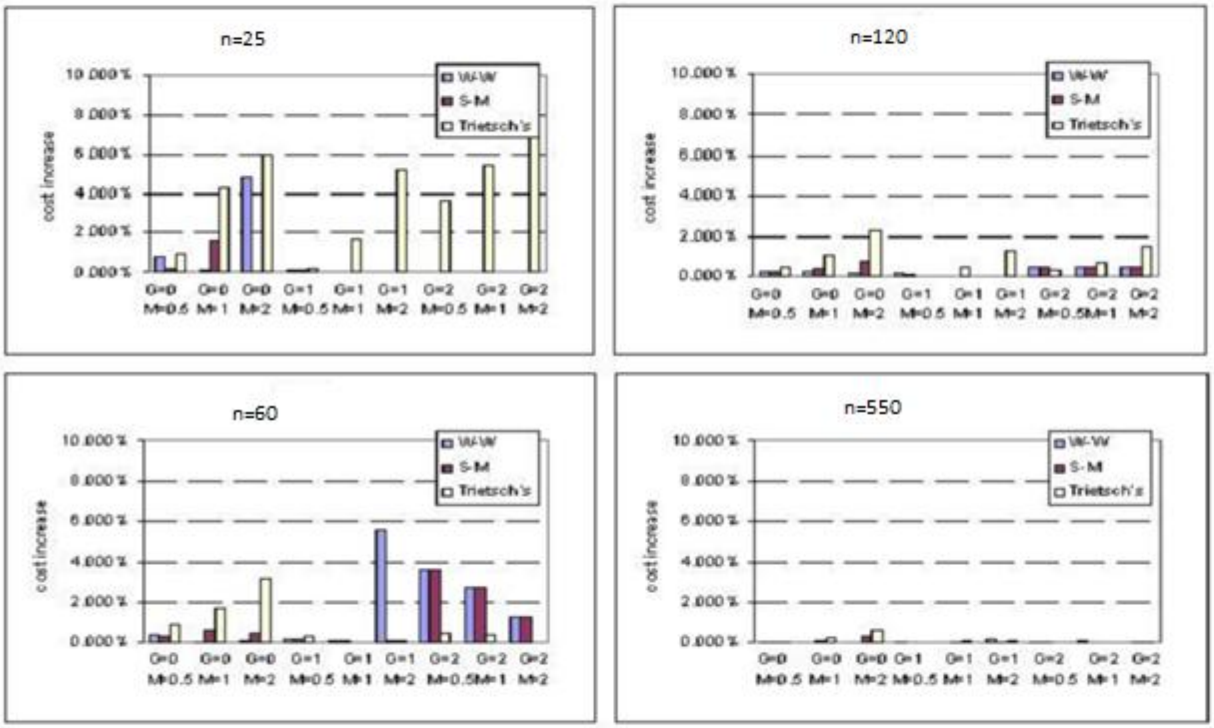

Figure 1: Case when σ_ϵ is over-estimated ($\sigma_\epsilon = 0 . 8$, $\sigma_\epsilon= 1$).
All of the cases presented in Table-1 are investigated and compared

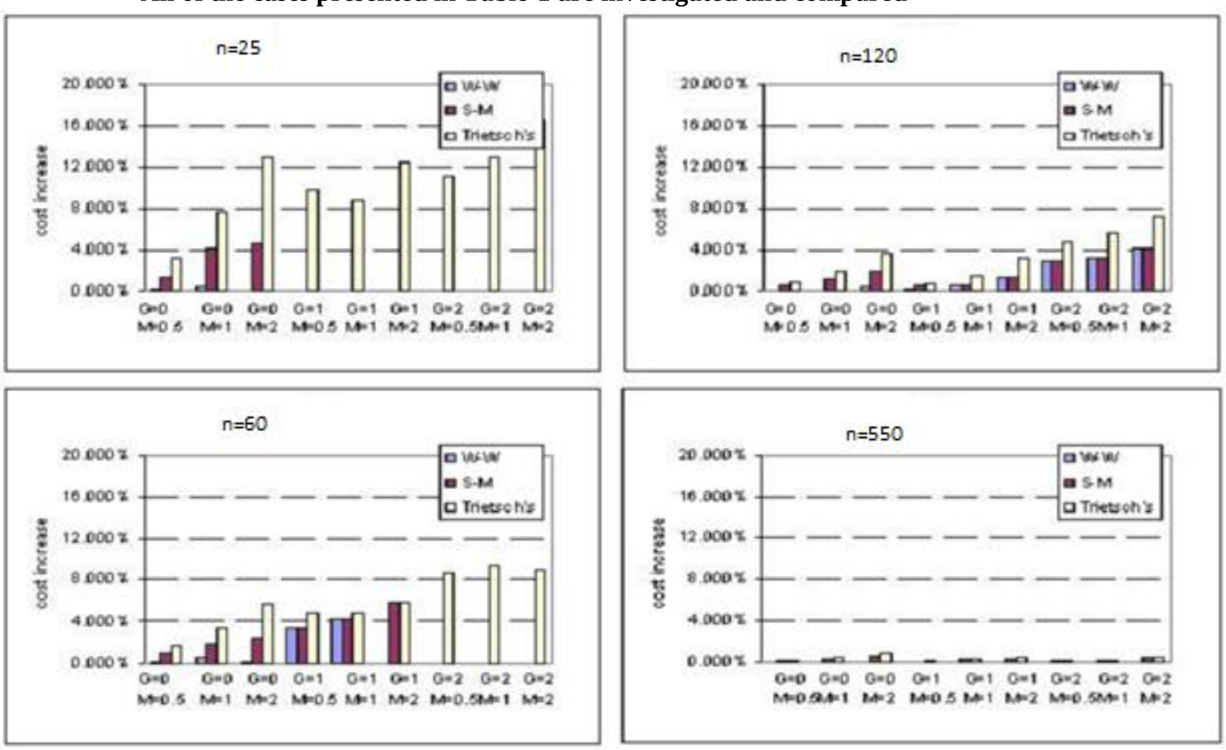

Figure 2: Case when σ_ϵ is under-estimated ($\sigma_\epsilon = 1.2$, $\sigma_\epsilon= 1$).

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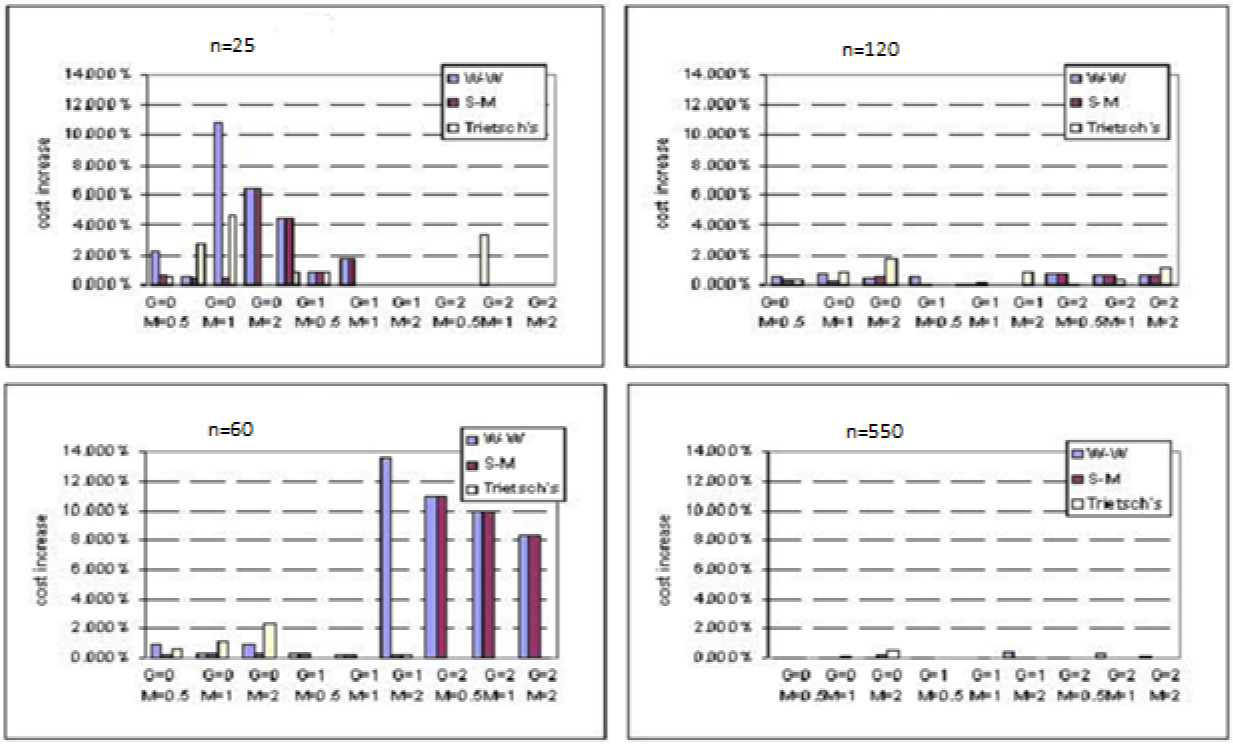

Fig. 3 Case when | d-d_0 | = σ_ϵ.

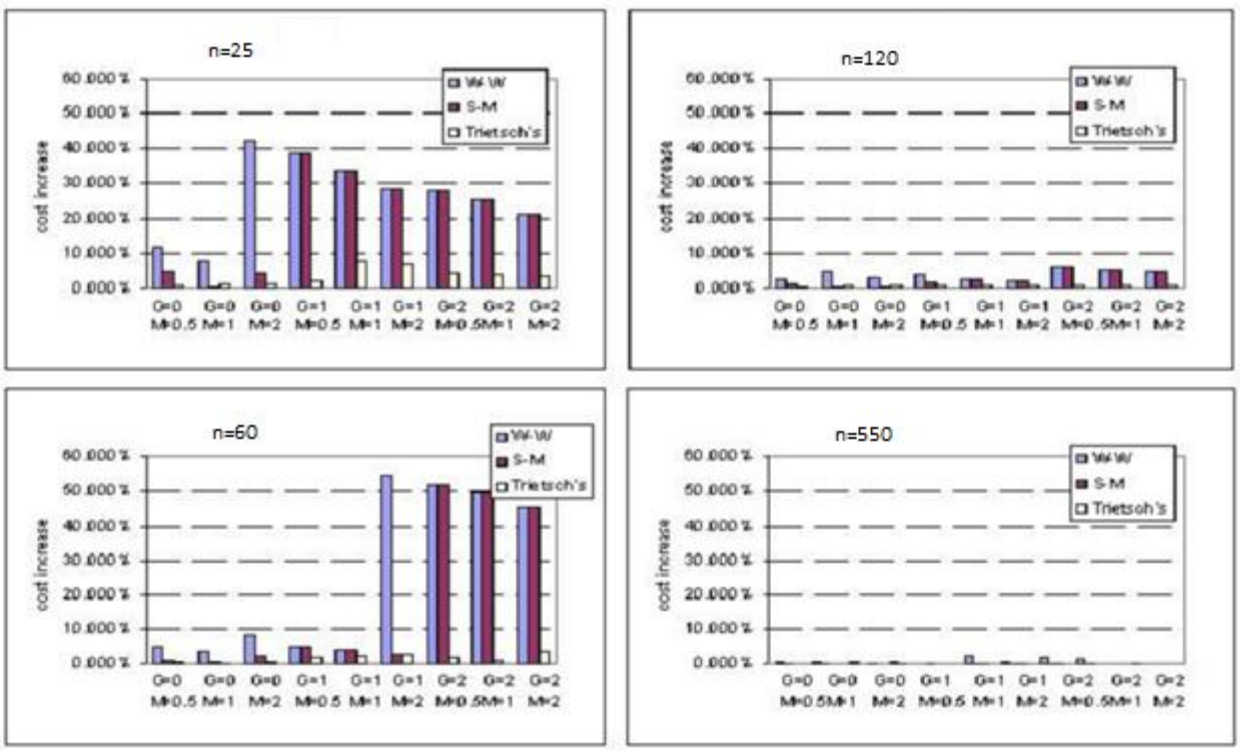

Fig.4 : Case when | d-d_0 | = 2σ_ϵ.

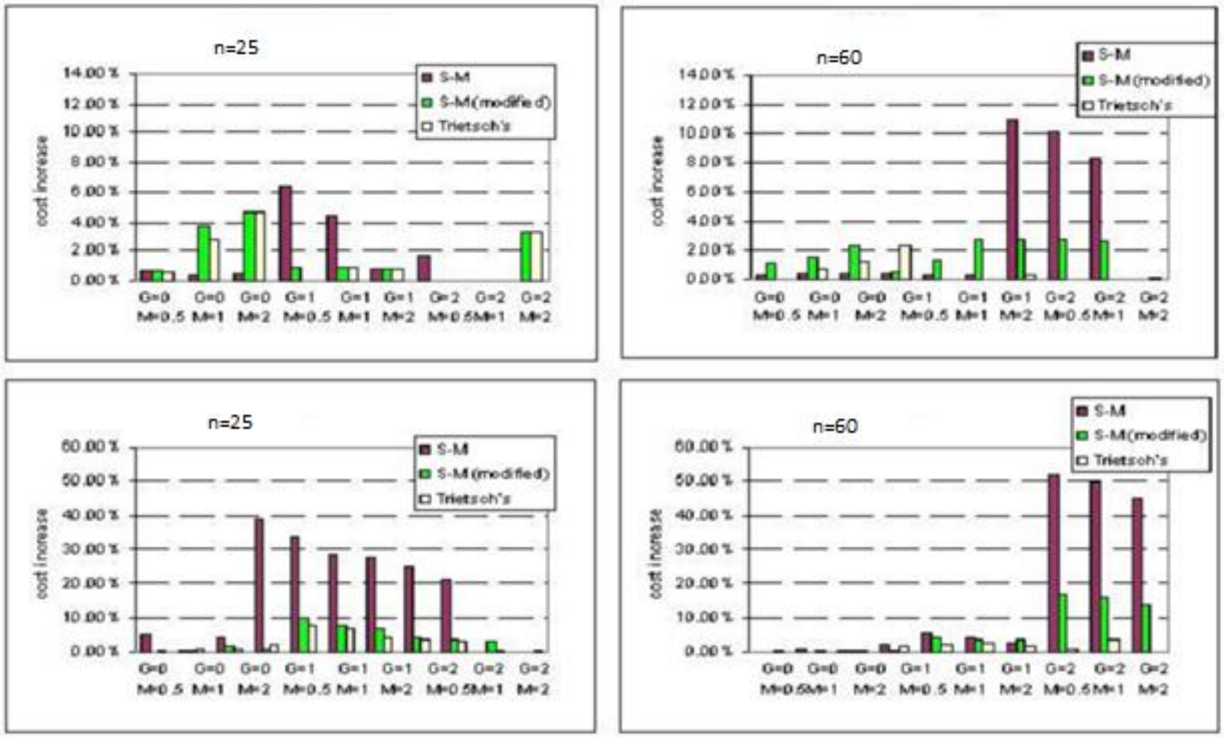

Fig. 5: Comparison of performance of the modified S-M heuristic and other methods when $|d-d_0| = 1\sigma_\epsilon$ or $|d-d_0| = 2\sigma_\epsilon$ and n=25 or n=60.

Conclusion :

The Three adjustment scheduling methods were compared which can achieve optimal or near optimal expected total manufacturing cost. The Wagner- Whitin method, a backward implementation of the Silver- Meal method and a method due to Trietsch. It was found that when the production runs are long, there is not significant difference between the performance of three methods. For a short-run manufacturing process, the proposed backward S- M method has the advantage of providing a close- to-optimal solution with small even when the process variance estimate is biased. A problem found with this method is that when there exists a significant bias on the initial estimate of the setup error and when the adjustment or the measurement costs are high, the schedule provided by the backward S-M method may incur in a much higher cost increase than Trietsch's method. As a solution to this drawback, it was demonstrated that simply adding one more adjustment close to the beginning of the schedule enhances the robustness of the backward S-M method.

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