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The Use of Earned Value Analysis in Production Control with Uncertainty Conditions

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Abstract

Multi Period–Multi Product (MPMP) production planning problems are well-known in the literature and several researches had been carried out in this area. However, designing a well organized control mechanism in terms of time–cost point of views had not been taken into considerations. In this paper, such a control mechanism is implemented successfully using earned value analysis which is well-known in project management context. The approach uses fuzzy progress measurement through earned value calculations where the nature of project is associated with uncertainty conditions. In this way, four different control chart approaches have proposed in order to detect the status of production using linguistic terms. The results in each case presented through the MPMP problem appropriately.

Keywords: control chart, production control, earned value analysis, fuzzy progress measurement

1 Introduction and Literature Review

Since planning occurs prior to the controlling actions in production and manufacturing environment, most researches in the literature have discussed production planning rather than the control approaches. However, it is obvious that planning without controlling action is not effective enough. In this respect, it is important to integrate both planning and control actions into a unique program accordingly. This implies that the production control must be carried out in accordance with an earlier plan. Otherwise, the production system performance (e.g. on-time and on-budget delivery to customer) cannot be accurately measured. In addition to the above mentioned advantages, actual records from a production planning horizon can be further used for future planning.

On the other hand, since an analytical model (e.g. linear programming technique) may generate an infeasible solution in practical problems due to its ignorance with respect to some cases during modeling (such as machine order visit), the literature indicates that hybrid analytical–simulation analysis can be efficiently performed [4]. That is the reason why optimization techniques such as linear programming models are unable to consider some operational criteria in a machine-shop such as machine order visit as proposed and modeled by Byrne and Bakir [4], Kim and Kim [15] and finally Byrne and Hossain [5]. It is also pointed out that they discussed about a Multi period–Multi product (MPMP) production planning problem where at each period, each product should be produced subject to some operational criteria such as machine order visit, machine capacity constraint, processing time of each operation to be proceed on each machine center and finally demand rate at each period, for each product is assumed to be deterministically known. In the approaches advocated by the above authors, the initial production plans have been generated by applying linear programming (LP) formulation /simulation analysis and then the results found by LP are taken as input to a simulation model in order to adjust capacity for producing each of the products. Finally, simulation analysis is stopped when the total output is feasible in accordance with capacity constraints and operational criteria available in the shop. On the other hand, in order to control manufacturing processes and production environments, some research papers were found to be focused mainly on shop floor control concepts as described in the following paragraphs which are not related to the MPMP problem. For instance, Monch [19] described benchmarking efforts for production control in complex manufacturing environment where large numbers of products, sequence dependent set up times, mixtures of different process types and internal–external disturbances were included. Monostori *et al.* [20]

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summarized the main challenges and issues associated with customized mass production control. They applied both traditional discrete event simulation and agent based approaches. Csajia *et al*. [9] presented an adaptive scheduling system which performs in a market based production control system thorough a triple level learning mechanism. Al-Tahata and Mukattash [2] designed production control schemes for Kanban based Just-in-Time (JIT) environments. For this reason, the Kanban system was formulated as a queuing model and a new approach was discussed for analyzing it. Gharbi and Kenné [11] addressed a production and maintenance control problem where multiple-machine manufacturing systems were considered. For both identical and non identical manufacturing systems, a two level hierarchical control model was developed.

In the leading researches around production control mechanism, rarely significant approaches found in the literature and it traditionally performed by comparing the planned and actual production rates at the end of each period.

However, our literature search does not find any research with a comprehensive approach incorporating production control especially during production process in MPMP problem. This presents a new open field in production control approaches which should be updated periodically.

On the other hand, due to uncertainty conditions associated with manufacturing and operating environments, it is thus desirable to model ambiguous situation embedded with operations in manufacturing and production context. In this area, there are some researches which mainly applied fuzzy control chart in different types and situations. In this regard, the first control chart was proposed by Shewhart [22] in 1920s which is still subject to new application areas. Further developments to improve the performance of control charts proposed by Shewhart [22] are on the basis of usage of probability and fuzzy set theory integrated with the control charts [13]. Fuzzy set theory is required to model the type of uncertainty which probability is not capable of modeling [17]. Dubois and Prade [10] declared that a stochastic decision method such as statistical decision analysis does not measure the imprecision in human behavior; on the other hand, fuzzy set theory captures the subjectivity of human behavior.

Marcucci [18] proposed two procedures using Shewhart-type control charts for linguistic terms. In control charts proposed by Kanagawa et al. [14] for process average and process variability, the probability distribution exists behind the linguistic data is taken into consideration. Taleb and Limam [23] proposed the comparison of fuzzy and probability approaches of constructing fuzzy control charts based on average run length.

Cheng [6] proposed the method of constructing a fuzzy control chart for a process with fuzzy outcomes. Fuzzy outcomes, in his paper, described in fuzzy numbers based on experts' quality ratings. Cheng [7] proposed fuzzy control charts constructed by fuzzy outcomes derived from the subjective quality ratings provided by a group of experts. Gűlbay and Kahraman [12] presented some contribution to fuzzy control charts base on fuzzy transformation methods which are made by utilization of α-cut which provides the ability to determine the tightness of the inspection properly. They developed an alternative approach "Direct Fuzzy Approach (DFA)".

However, as it is presented, fuzzy control charts and relevant approaches had not been used through manufacturing environment. Maybe that is why, in order to apply control charts, firstly the results should be expressed within a couple of indexes and formula, and then the results would be under control accordingly.

It is thus possible to convert to another environment and calculate relevant indexes such as earned value analysis (EVA) which is well-known in project management context. EVA usually represents project performance index from both cost and time status point of view. The importance of applying earned value analysis in manufacturing mainly comes from two reasons. The first item is that EVA is able to provide performance report based on achieved progress during manufacturing process and making alert in case of undesirable outcomes. The second reason, hereby, is that EVA also is able to present two indexes namely Schedule Performance Index (SPI), and Cost performance Index (CPI) which will be taken into consideration as a basis through designing a control mechanism within manufacturing environment. Thus, the problem of converting manufacturing context to a measurable condition is now solved. Consequently, it incorporates in designing control mechanism through production and manufacturing problems. It is also pointed out that most usage of EVA had been included through out project and organization environments.

As an important research work on earned value analysis and forecasting features, Vandevoorde and Vanhoucke [24] not only concentrated on traditional EV metrics, but also developed earned schedule performance indicator namely SV(t) and SPI(t). Their proposed approach was also able to yield forecast of total project duration. Vitner et al. [25] applied a data envelopment analysis (DEA) for performance evaluation in a multi project environment where each project was defined uniquely. They integrated EV management system (EVMS) with multi denominational control system (MPCS). Cioffi [8] presented a new formalism for notations used in EV analysis and reproduced standard EV parameters. He also presented additional quantities defined there. Kim et al. [16] developed a model based on research effort on a two year period in different types of projects and organizations, e.g. public and private organizations as well as large and small projects. Moslehi [21] presented an integrated web based time and cost control system for construction projects which mapped work breakdown structure (WBS) into an object oriented model to enable generating EV reports at control objects, and resource levels. Al-Jibouri [1] evaluated effectiveness of three monitoring systems namely leading parameters technique, variance method and activity based ratio technique in construction projects from both theoretical and experimental points of view.

In the leading researches around production control mechanism, rarely significant approaches found in the literature and it traditionally performed by comparing the planned and actual production rates at the end of each period. To the bests of our knowledge, no closely related research found covering problem under consideration in this paper.

As a related work in this area, Noori et al. [29] presented implementation of earned value analysis through MPMP problem in order to detect status in linguistic terms such as rather in control as well as traditional indexes such as poor, good, etc. However, the structure of this paper is different from mentioned available researches in controlling MPMP problems. Also, Bagherpour et al. [28] presented designing a control mechanism through MPMP problems where processing times have been considered as fuzzy numbers by means of EVA. They also focused on SPI and CPI through MPMP cases, however, the concept and modeling procedure is different. For instance, in this paper processing times are deterministically considered.

This paper is organized as follows. The fuzzy approach of considering progress uncertainty and the effect of this consideration on EVA is presented in Section 2. In Section 3, the proposed approach is illustrated and finally through implementing the proposed approach on a case study given in [4, 5, 15]. In Section 4, the validity of the proposed method is demonstrated.

2 Fuzzy Progress

The fuzzy progress is represented by a trapezoidal fuzzy number (a,b,c,d) (Fig. 1) or a triangular fuzzy number (a,b,d) or (a,c,d) (Fig. 2) [27].

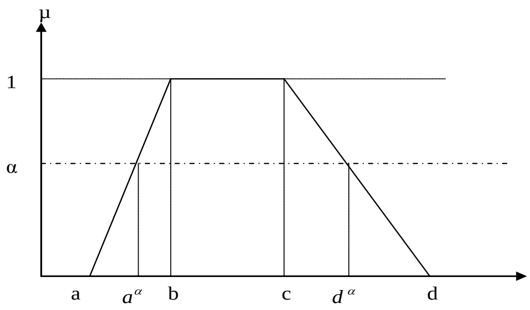

Figure 1: Trapezoidal fuzzy number

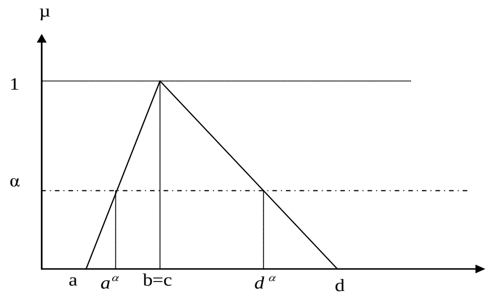

Figure 2: Triangular fuzzy number

Note that when b = c, a trapezoidal fuzzy umber becomes a triangular fuzzy number. The triangular fuzzy number can also be represented by trapezoidal fuzzy number notation as (a,b,b,d) or (a,c,c,d).

The α-cut of fuzzy number Ã is defined as

$$\widetilde{A}^{\alpha} = \{x_i : \mu_{\widetilde{A}}(x_i) \geq \alpha, x_i \in X\} \tag{1}$$

where $\widetilde{A}^{\alpha}$ is the set of members of Ã with membership degree greater than or equal to α [27]. Applying α-cut to triangular and trapezoidal fuzzy number (Fig. 1), the values of lower bound (a^α) and upper bound (c^α) are determined as follows:

$$a^{\alpha} = a + \alpha(b-a), \tag{2}$$

$$c^{\alpha} = b + \alpha(c-b). \tag{3}$$

There is usually uncertainty in estimating the progress of project or completed percent of the project. Therefore in this research the %progress is shown by trapezoidal fuzzy number, i.e., $\%(P_a, P_b, P_c, P_d)$.

Based on percent-complete method, Earned Value (EV) is equal to multiplication of Budget at Completion (BAC) by percentage of the work completed, i.e., EV = BAC × % progress. Since %progress is defined by trapezoidal fuzzy number, EV will be a trapezoidal fuzzy number, consequently,

$$\widetilde{EV} = BAC \times \% \tilde{P}. \quad (4)$$

3 Proposed Method

The method proposed in this paper is based on calculating earned value indexes (CPI and SPI) by consideration of fuzzy progress values and determining the cost and schedule condition by applying the control chart proposed by Anbari [3]. In the control chart proposed by Anbari [3], the condition of project performance (cost or schedule) is determined by linguistic words as: Poor, Caution, Good, Super Star. In this paper, the condition of project performance by considering the linguistic words and fuzzy values on project indexes, i.e., CPI, SPI is being treated.

Following the calculation method of CPI and SPI is presented, the SPI and CPI control charts are illustrated.

3.1 Schedule Control

The schedule performance index (SPI) is a measure of schedule performance and is calculated via dividing earned value (EV) by actual cost (AC) i.e. SPI = EV/AC. This index is used to determine the project schedule condition whether it is ahead of or behind the schedule.

As presented previously, declaring progress in project by fuzzy numbers affects the earned value amount changing to fuzzy number. Since SPI is calculated via dividing earned value (EV) by actual cost (AC), the SPI turns out to fuzzy number and is calculated as follows.

$$\widetilde{SPI} = \frac{\widetilde{EV}}{AC}. \quad (5)$$

3.2 Cost Control

The CPI measures the budgetary conformance of actual cost of work performed and is equal to division of earned value (EV) to actual cost (AC), i.e. CPI = EV/PV.

Since earned value (EV) is fuzzy number, the CPI will be fuzzy number and is calculated as follows.

$$\widetilde{CPI} = \frac{\widetilde{EV}}{PV}. \quad (6)$$

Following different methods of dealing with fuzzy values of CPI and SPI are presented.

3.3 CPI and SPI Control Chart Based on Utilizing Yager Ranking Index

Yager [26] proposed a procedure for ordering fuzzy sets based on the concept of area compensation. Area compensation possesses the property of linearity. A ranking index $I(\tilde{t})$ is calculated for the convex fuzzy number $\tilde{t}$ from its α-cut $\alpha_{\tilde{t}} = [t_L^\alpha, t_U^\alpha]$ according to the following formula:

$$I(\tilde{t}) = \int_0^1 \frac{1}{2}(t_L^\alpha + t_U^\alpha) d\alpha. \quad (7)$$

Yager ranking index is used as a transformation method for the membership functions of $\widetilde{CPI}$ and $\widetilde{SPI}$.

$$I(\widetilde{CPI}) = \int_0^1 \frac{1}{2}((CPI)_L^\alpha + (CPI)_U^\alpha) d\alpha. \quad (8)$$

As the Yager indexes of CPI and SPI are calculated, different cost and schedule condition will be determined by applying CPI and SPI control chart proposed by Anbari [3]. Different cost conditions of project by applying Yager ranking index to CPI is presented in Fig. 3. It results in four conditions accordingly.

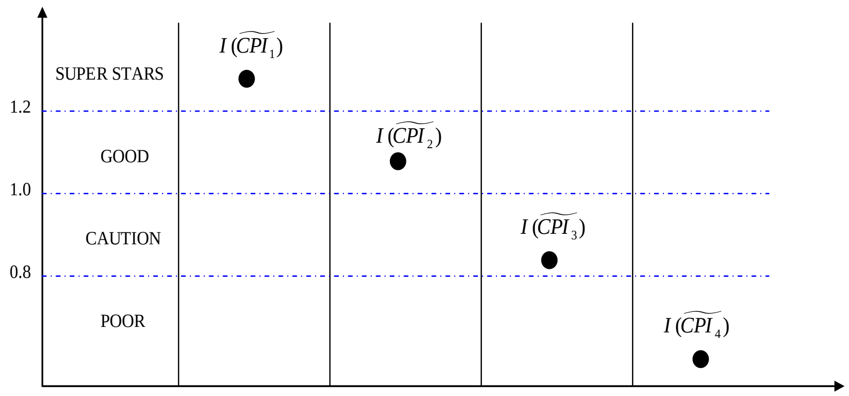

Figure 3: Different cost condition of project: Yager ranking method

3.4 CPI and SPI Control Chart Based on α-level Fuzzy Midrange Transformation

The α-level fuzzy midrange of $\widetilde{CPI}$ is the midpoint of the ends of α-cut. If $(\widetilde{CPI})_a^\alpha$ and $(\widetilde{CPI})_d^\alpha$ are the end points of α-cut, then the α-level fuzzy midrange ($(\widetilde{CPI})_{mr}^\alpha$) will be calculated as follows:

$$(\widetilde{CPI})_{mr}^\alpha = \frac{1}{2}((\widetilde{CPI})_a^\alpha + (\widetilde{CPI})_b^\alpha). \tag{9}$$

The α-level fuzzy midrange of $\widetilde{SPI}$ is calculated the same as $\widetilde{CPI}$. Different cost conditions of project resulted from considering control chart proposed by Anbari [3] and applying α-level fuzzy midrange method is presented in Fig. 4. It is obvious that the method proposed for CPI index can also be used for SPI index. The fact that the result of applying α-level fuzzy midrange method to CPI and SPI is a crisp number resultes in four different conditions.

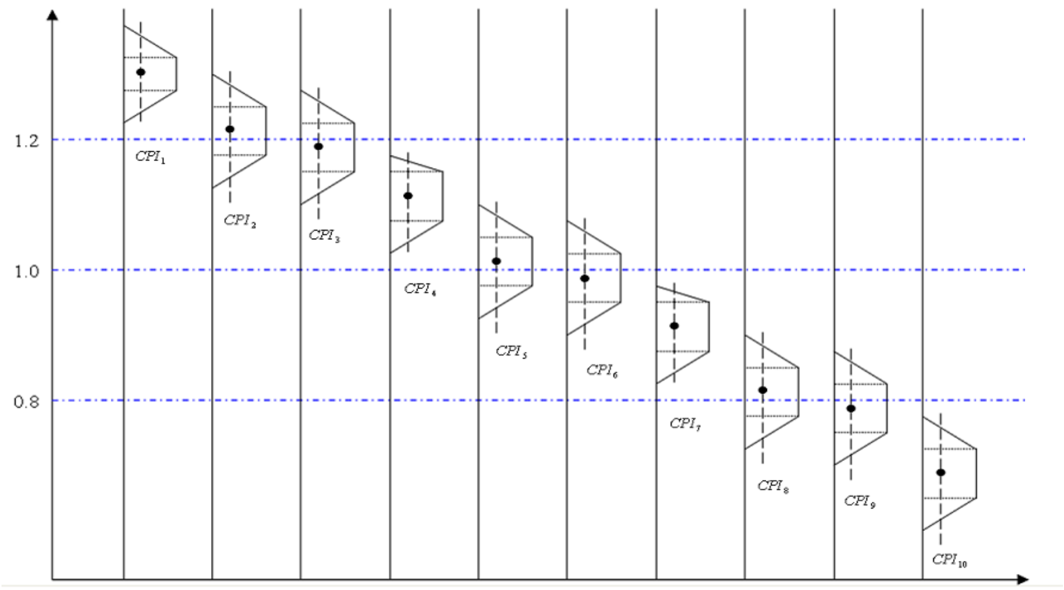

Figure 4: Different cost condition of project: α-level fuzzy midrange transformation method

CPI samples illustrated in Fig. 4 results in four types of different cost conditions: CPI_1, CPI_2: “super-star”, CPI_3, CPI_4, CPI_5: “good”, CPI_6, CPI_7, CPI_8: “caution”, CPI_9, CPI_{10}: “poor”.

3.5 CPI and SPI Control Chart Based on Fuzzy Mode Transformation

The fuzzy mode of a fuzzy set A is stated as follow:

$$A_{mod} = \{x_i : \mu_{\tilde{A}}(x_i) = 1, x_i \in X\} \tag{10}$$

where A_{mod} is the set of members of Ã with membership degree equal to1 [27].

Fuzzy mode of $\widetilde{CPI}$ and $\widetilde{SPI}$ are compared to control values: 0.8, 1, 1.2 to determine the project cost and schedule condition, respectively. Suppose the $\widetilde{CPI}$ is represented as $(CPI_a, CPI_b, CPI_c, CPI_d)$. For a $\widetilde{CPI}$, whose fuzzy mode is partially included in the set of control limits, the percentage of fuzzy mode falling between control values will be calculated and compared to a predefined percentage (β), and then the cost control condition will be identified. Following, different cost conditions based on different value of fuzzy mode boundaries of $\widetilde{CPI}$ are presented.

Table 1: Determining different cost condition: fuzzy mode transformation

CPI	Cost Condition
$CPI_b \geq 1.2$	Super star
$CPI_b \geq 1$ and $CPI_c \leq 1.2$	Good
$CPI_b \geq 0.8$ and $CPI_c \leq 1$	Caution
$CPI_c \leq 0.8$	Poor
$CPI_b \leq 1.2$ and $CPI_c \geq 1.2$	$\beta_1 = \frac{CPI_c - 1.2}{CPI_c - CPI_b}$
$CPI_b \leq 1$ and $CPI_c \geq 1$	$\beta_2 = \frac{CPI_c - 1}{CPI_c - CPI_b}$
$CPI_b \leq 0.8$ and $CPI_c \geq 0.8$	$\beta_3 = \frac{CPI_c - 0.8}{CPI_c - CPI_b}$

Alternatively, for a $\widetilde{CPI}$ which β_i is calculated, the value of β_i can be compared to a predefined acceptable percentage (β) and cost condition would be defined as follows:

If $\beta_1 \geq \beta$, it is “rather super star”. Else it is “rather good”.

If $\beta_2 \geq \beta$, it is “rather good”. Else it is “rather caution”.

If $\beta_3 \geq \beta$, it is “rather caution”. Else it is “rather poor”.

Note that the value of β can subjectively be defined by the experts’ experiences or directly by the project manager and it declares how much optimism they are about determining the project cost and schedule condition.

It is obvious that the method proposed for CPI index can also be used for SPI index. Following samples of different cost conditions in CPI control chart is presented.

Assume that $\beta = 0.5$, CPI samples illustrated in Fig.5 results in ten types of different decisions: CPI_1: “super-star”, CPI_2: “rather super-star”, CPI_3:“rather-good”, CPI_4: “good”, CPI_5: “rather-good”, CPI_6: “rather-caution”, CPI_7: “caution”, CPI_8: “rather-caution”, CPI_9: “rather-poor”, CPI_{10}: “poor”.

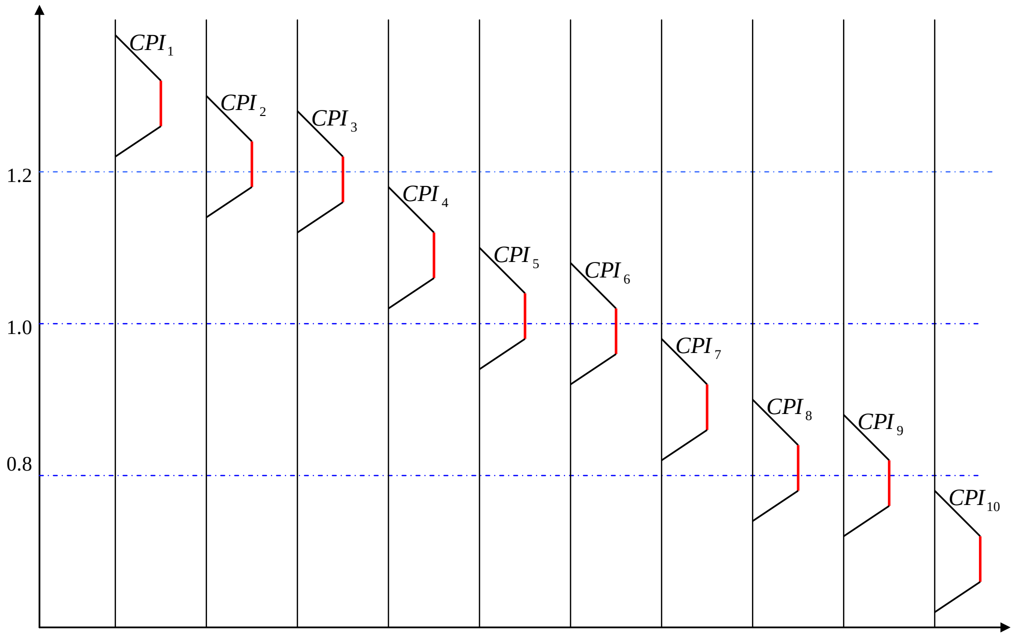

Figure 5: Different cost conditions of project: fuzzy mode transformation method

3.6 CPI and SPI Control Chart Based on Percentage Area inside Regions Method

In this approach, $\widetilde{CPI}$ and $\widetilde{SPI}$ are not transformed to crisp numbers using fuzzy transformation. Therefore, $\widetilde{CPI}$ and $\widetilde{SPI}$ are applied to control chart directly in order not to lose any information included in their natures.

The cost and schedule condition of project is determined according to the percentage area of the $\widetilde{CPI}$ and $\widetilde{SPI}$ remain inside different control chart regions. Following different cost condition of project based on this approach is presented. Since $\widetilde{CPI}$ and $\widetilde{SPI}$ are both considered as trapezoidal fuzzy numbers, following cost condition determination presented in Table 2 can be applied for $\widetilde{SPI}$, too.

Table 2: Determining different cost condition: percentage area inside regions method

CPI	Cost Condition
$CPI_a \geq 1.2$	Super star
$CPI_a \geq 1$ and $CPI_d \leq 1.2$	Good
$SPI_a \geq 0.8$ and $CPI_d \leq 1$	Caution
$CPI_d \leq 0.8$	Poor
$CPI_a \leq 1.2$ and $CPI_d \geq 1.2$	$\beta_1 = \dfrac{CPI_c + CPI_d - 2.4}{(CPI_d + CPI_c - CPI_b - CPI_a)\times 0.5}$
$CPI_d \geq 1$ and $CPI_a \leq 1$	$\beta_2 = \dfrac{CPI_c + CPI_d - 2}{(CPI_d + CPI_c - CPI_b - CPI_a)\times 0.5}$
$CPI_a \geq 0.8$ and $CPI_d \leq 0.8$	$\beta_3 = \dfrac{CPI_c + CPI_d - 1.6}{(CPI_d + CPI_c - CPI_b - CPI_a)\times 0.5}$

If $\widetilde{CPI}$ is partially included by the control limits (0.8, 1, 1.2), the area above the control limit is divided by the whole CPI area to determine the value of β_i. The value of β_i can be compared to a predefined acceptable percentage (β) and cost condition would be defined as follows:

If $\beta_1 \geq \beta$, it is "rather super star". Else it is "rather good".

If $\beta_2 \geq \beta$, it is "rather good". Else it is "rather caution".

If $\beta_3 \geq \beta$, it is "rather caution". Else it is "rather poor".

Following samples of different cost conditions in CPI control chart is presented.

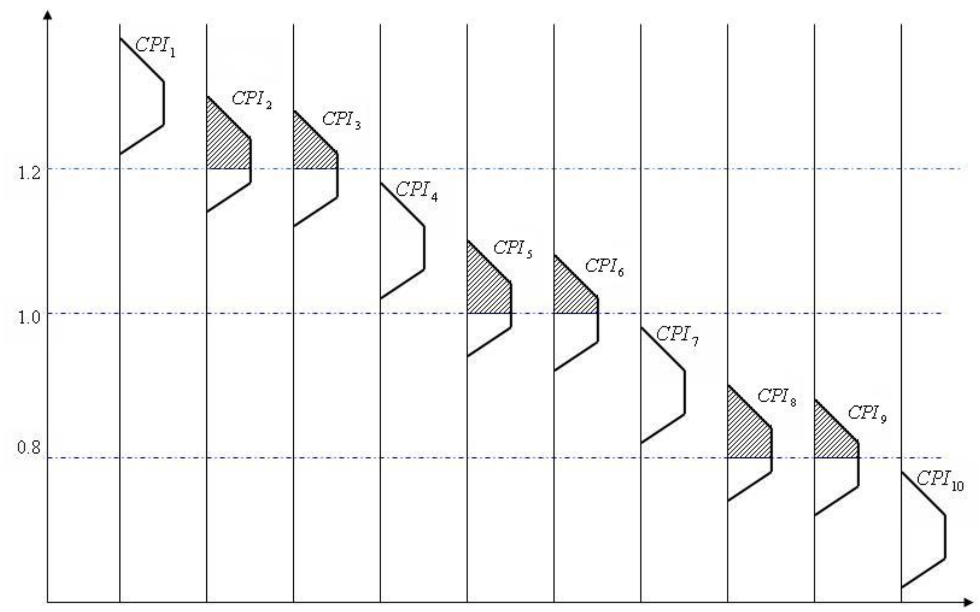

Figure 6: Different cost conditions of project: Percentage area inside regions method

Assume that $\beta = 0.5$, CPI samples illustrated in Fig.6 results in ten types of different decisions: CPI_1: "super-star", CPI_2: "rather super-star", CPI_3: "rather-good", CPI_4: "good", CPI_5: "rather-good", CPI_6: "rather-caution", CPI_7: "caution", CPI_8: "rather-caution", CPI_9: "rather-poor", CPI_{10}: "poor".

4 Numerical Example

A case study given in [4, 15, 5] is used. The case study is a three period three product production planning problem that has to process through four machining centers, each includes one machine and one input buffer. The capacity constraint for each machine is equal to 2400 minutes per week. The processing times are given in Table 3. The costs components and coefficients for each product and at each period are given in Table 1. Also demand of customer and process routines are given through Tables 2 and 4.

Table 3: Cost components

	Unit production cost			Inventory holding cost			Shortage cost		
Periods	1	2	3	1	2	3	1	2	3
Products									
1	100	100	100	25	25	100	400	400	400
2	150	150	150	30	30	150	450	450	450
3	125	125	125	35	35	200	500	500	500

Table4: Customer demand

		Periods		
		1	2	3
Products	1	150	125	160
	2	100	150	150
	3	125	165	125

Table5: Processing times

		Machining centre			
		MC1	MC2	MC3	MC4
Products	1	5	-	4	10
	2	7	7	5	-
	3	7	6	10	-

Table6: Machine visit order

		Machine visit order		
Product	1	MC1	MC4	MC3
	2	MC1	MC2	MC3
	3	MC1	MC2	MC3

Based on data observed in multi period–multi product production planning problem, a detailed time schedule is constructed as given in Fig. 7.

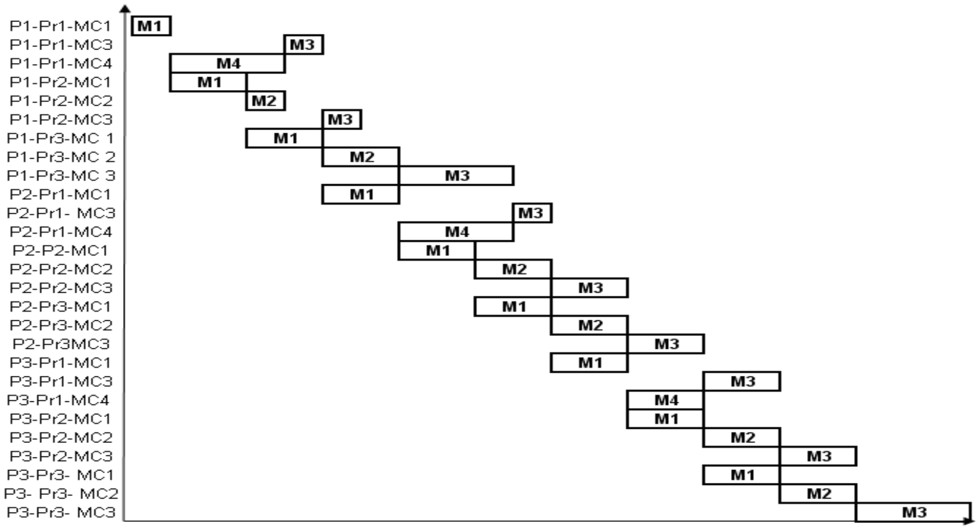

Figure 7: Detailed time schedule for case study

Suppose we are in the end of 10th day of the project and the actual cost and progress values till the 10th day is shown in Table 7.

Table 7: Actual cost and fuzzy progress values

Day		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cumulative Actual Cost		3000	7500	16500	29000	43500	55500	66500	76000	84000	102000
%Progress	a	0.5	0.55	0.65	0.72	0.76	0.8	0.85	0.83	0.82	0.6
	b	0.6	0.6	0.7	0.8	0.85	0.82	0.9	0.85	0.85	0.81
	c	0.62	0.65	0.73	0.82	0.86	0.83	0.9	0.87	0.87	0.84
	d	0.7	0.7	0.8	0.85	0.9	0.85	0.92	0.9	0.9	0.91

Based on different approaches proposed in Section 3, the linguistic conditions of the schedule cost and performance condition in 10th day of production are determined.

The fuzzy CPI and SPI values in 10th day are transformed to crisp numbers using Yager ranking index (8). The linguistic conditions of these values are determined using the classic CPI, SPI control chart (Table 8).

Table 8: Cost and schedule condition using Yager ranking index

	SPI	CPI
Yager Ranking Index	0.807	0.787
Condition	Poor	Caution

Using fuzzy midrange transformation and fuzzy mode transformation approaches described in Sections 3.4 and 3.5, the cost and schedule conditions are determined in Tables 9 and 10, respectively. By evaluating mode and midrange of CPI and SPI values, and then referring the conditions described in Sections 3.4 and 3.5, the conditions are resulted.

Table 9: Cost condition based on fuzzy midrange and fuzzy mode (α =0.5, β= 0.5)

	$(\widetilde{CPI})_{mr}^{0.5}$	$(\widetilde{CPI})_{mr}^{0.5}$ condition	$(CPI)_{\text{mod}}$	β_i	$(CPI)_{\text{mod}}$ condition
$\widetilde{CPI}$	0.787	Poor	(0.785, 0.803)	18.9	Rather Poor

Table 10: Schedule condition based on fuzzy midrange and fuzzy mode (α =0.5, β= 0.5)

	$(\widetilde{SPI})_{mr}^{0.5}$	$(\widetilde{SPI})_{mr}^{0.5}$ condition	$(SPI)_{\text{mod}}$	β_i	$(SPI)_{\text{mod}}$ condition
$\widetilde{SPI}$	0.807	Caution	(0.805, 0.823)	100%	Caution

Based on percentage area inside regions method described in Section 3.6, the cost and schedule performance conditions are determined and shown in Table 11. Considering the conditions described in Section 3.6, the result is Table 11.

Table 11: Conditions based on percentage area inside regions

	Whole area	Area above the control limits	β_i	Condition
$\widetilde{CPI}$	0.070	0.45	0.645	Rather Caution
$\widetilde{SPI}$	0.072	-	-	Caution

The conditions related to different fuzzy CPI and SPI values in 10th day are defined and the production manager can decide based on the linguistic descriptions which actions to be taken into account on the production processes.

5 Conclusion

In this paper, four different control chart approaches based on Yager ranking method, α-level fuzzy midrange transformation, fuzzy mode transformation, and percentage area inside regions method are proposed in order to draw a control mechanism through production control where process times to be performed can not expressed deterministically due to uncertainty conditions associated with job processing. As an important factor, the results have been presented linguistically in terms of different situations and it is further selected by production manager to implement the best known in accordance with situation available in the shop. The approach can be also useful for the manufacturer in order to control performance achieved at the end of each control period and it would also be periodically updated. Further research can be conducted on applying proposed four methods in a real case manufacturing problem and then discuss the challenges, advantages and disadvantages of designed control mechanism in accordance to achieved information resulting from actual data. As another future research, it is also recommended to design a control approach for MPMP cases by means of EVA where all of relevant parameters have been considered as fuzzy numbers resulting from uncertainty conditions available in the shop floor.

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