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SELECTION OF CNC LATHE MACHINE BY USING AXIOMATIC PRINCIPLES

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Abstract: Hitherto the researchers had been studied the number of theoretical and practical approach related to the axiomatic design (AD) principles. Now a day selecting the various instrument and machine is vital for any engineer. In this research applies the Axiomatic design (AD) theory in selecting the CNC lathe machine, and then presents a new concept for the selecting the machine. Set the various Functional requirement (FR) and collecting the various CNC lathe machine data and plotting the graphs then find the probability of all data. A successful application of AD in selecting the CNC lathe machine.

Keywords: CNC lathe machines, Axiomatic principles, MOORA, TOPSIS, and DEA.

I. INTRODUCTION

Now a days competition conditions have carried customer needs to an effective position in all decisions related to service and production systems. In world, many peoples have different-different things and their different need so that there are a wide range of customer needs affecting decision makers in many decisions on product design and system design to find the most appropriate alternatives. Many new models, which predicate on Axiom Design principles, have been developed in the last few years to include these needs within the decision-making process with a systematic approach and to present comprehensive solution suggestions to decision makers [6, 24].

Axioms are general principles which are evident actualities that cannot be proven to be correct but which do not have counter examples . AD principles developed by Suh[6, 24]to form systematic scientific basis for designers, especially in the design processes of product, production systems, and software design are widely used to solve many design problems. These principles present better design solutions in the shortest time as they provide a systematic research process in a design space, which becomes complicated with customer needs. In addition, the fact that axioms can be generalized allows this method to be effective and powerful in different design areas [6, 24].

In the last recent years, new studies aiming at solving multi-criteria decision-making problems based on Axiom Design principles have been presented. Axiom Design principles, which allow for the selection of not only the best alternative within a set of criteria but also the most suitable alternative, show a great difference when compared with other method and alternatives. Additionally, Axiom Design principles also have differences in comparison with other methods due they can evaluate design alternatives with respect to the criteria including both crisp and fuzzy values in a multi-criteria decision making problem. The number of studies using Axiom Design principles is gradually increasing as Axiom Design's superiorities create important advantages for decision makers in solving multi-criteria decision-making problems [6, 24].
Although there have been quite a number of theoretical and practical studies where Axiom Design principles have been used in the last recent years, a comprehensive literature survey which evaluates and classifies them does not exist. In this research the studies using Axiom Design principles have been classified with respect to the axioms they use for selection of CNC machine in range of our criteria. The reasons for their widespread usage have been researched within the extent of this study [6, 24].

II. LITERATURESURVEY

A. Based on axiom:

- Multi-attribute equipment selection is a vital activity for an effective manufacturing system. In this paper, include both crisp and fuzzy criteria. These approaches were applied to the selection among punching machines while investing in a manufacturing system. Osman Kulak and Cengiz Kahraman [5] using above approaches and gives the results, (1) Punch C is the best alternative when only consider the information content and (2) Punch B is the most suitable alternative when consider the weighted information content [5].

- The main function of the indicators used in a human machine system is to satisfy the interaction between human and machine. The indicator panel design for cars based on fuzzy axiomatic design principle. In this paper Selcuk Cebi and Cengiz Kahraman [7] 18 indicator panel designsare evaluatedby experts with respect to the defined functional requirements and suggested the A1 indicator panel design is well-suited [7].

- Periodic docking facilities for ship maintains in ship management companies are critical condition of ship managers. For solving this problem Metin Celik and Cengiz Kahraman [3] were used multiple criteria fuzzy axiomatic design (FAD) approach for selecting among shipyard alternatives with respect to the common policies of ship management companies. They finally gives results GEMAK is most suitable shipyards in Tuzla region [3].

- The traction ability of existing in-pipe robots is coupled with the velocity and up limited by the friction between robot and the inner wall of pipeline. Jinwei Qiao and Jianzhong Shang [2] applies the Axiomatic design (AD) theory in evaluation of existing in-pipe robots, and then presents a new concept of in-pipe robot. A successful application of ADin in-pipe robot design, which makes it possible that the moving velocity and traction ability can be designed or adjusted individually. All in-pipe robots were divided into three classed based on their different contact style with pipeline. After a calculation of the maximum traction ability, it proves the possibility of the powerful traction ability, which successfully decoupled the constraint from supportive mechanism for adjusting traction ability [2].

- The aim of this paper is to apply axiomatic design theory to the design of heat ventilation and air-conditioning (HVAC) systems and to come to conclusions about the design quality of some specific applications. According to the AD's first axiom, ideal systems are independent or decoupled. Miguel Cavique and A.M. Goncalves Coelho [4] give conclusion that VAV and DOAS with induction units are coupled designs, and on the other end, DOAS with fan-coils or chilled ceilings are decoupled designs [4].

- The main engine selection problem is not simple because it has a strong influence on the determination of the principal dimensions, arrangement, and propeller. An engine is assumed for calculating the lightweight of a ship and determining the arrangement, and then the resistance and the required power corresponding to those decisions are calculated. Beom-Seon Jang and Young-Soon Yang [1] were used the axiomatic principle foe selecting the main engine and give the results 6S50MC-C had the minimum total information content, it is thus selected as the best solution [1].

B. Based on other method:

- This paper reports on an application of data envelopment analysis (DEA) to evaluate computer numerical control (CNC) machines in terms of system specification and cost. SHINN SUN [8] taken 21 CNC lathe machines and seven criteria. They applied DEA method and based on the results of the vendor assessment, the VTURN 16 was selected as the most suitable machine by considering plant capacity, product quality, delivery requirements, and vendor reputation [8].

- Selection of proper machine tool is one of the important issues for achieving high competitiveness in the global market. This paper presents a logical and systematic procedure to evaluate the computer numerical control (CNC) machines. Shankar Chakraborty and Vijay Manikrao Athawale [9] taken 21 CNC lathe machines and seven criteria. They using the TOPSIS method and give the result that VTURN 16 best alternative as per selecting the criteria [9].

- The selection decisions become more complex as the decision makers in the manufacturing environment have to assess a wide range of alternatives based on a set of various criteria. Shankar Chakraborty [10] was applied MOORA method and give the result that VTURN 16 best alternative as per selecting the criteria [10].

- The selection of appropriate machines is one of the most critical decisions in the design and development of an efficient production. They used AHP, Reliability, cost and precision analyses. Emrah Çimren, Bulent Çatay and Erhan Budak [11] first consider qualitative decision criteria that are related to the machine properties. They used six alternatives & six criteria and give the results that (1) when used AHP and cost analysis than M2 was best alternative, (2) when used reliability analysis than V2 was best alternative, and (3) when used precision analysis than V3 was best alternative [11].

- For manufacturing companies, one of the starting points to achieving high competitiveness in the market is the selection of machine tools. AHP and ANP are applied in calculation of the contributions of machine tool alternatives to the manufacturing strategy of a manufacturing organization. Mustafa Yurdakul [12] taken four alternatives & three criteria. He applied Analytic network process (ANP), Analytic hierarchy process (AHP) and give results that VARIAXIS 500 was the best alternative [12].

- In this paper a decision support system is presented for machine tool selection in flexible manufacturing cell using fuzzy analytic hierarchy process (fuzzy AHP) and artificial neural network (ANN). The Priority weights of the Evaluation Criteria and Alter- native's Ranking called PECAR for fuzzy AHP model. Zahari Taha, Sarkawt Rostam [13] taken four alternatives and nine criteria. They applied fuzzy AHP, ANN with fuzzy AHP and ANN without fuzzy AHP and give results that (1) when used fuzzy AHP and ANN with fuzzy AHP than Nakamura alternatives was best, (2) when used ANN without fuzzy AHP than Mazak alternatives was best [13].

- The equipment selection process decides the quality, cost, and reliability, which are important for customer satisfaction. A proper equipment selection is a vital activity for manufacturing systems due to the fact that improper equipment selection can negatively affect the overall performance and productivity of a manufacturing system. In this paper, V. Paramasivam, V. Senthil and N. Rajam Ramasamy [14] used three multi-attributes decision-making methods, namely, digraph and matrix approach, analytical hierarchical process (AHP), and analytical network process (ANP). They take five alternatives and six criteria. They applied above method on CNC milling machines and give the results that M5 alternatives was best [14].

- Multi-attribute equipment selection is a very important issue for an effective manufacturing system, since the improper equipment selection might cause many problems affecting productivity, precision, flexibility and quality of the products negatively. In this paper, Metin Dagdeviren [15] used an integrated approach which employs analytic hierarchy process (AHP) and preference ranking organization method for enrichment evaluations (PROMETHEE) together, is proposed for the equipment selection problem. He take five alternatives and six criteria. He applied above method on CNC milling machines and give the results that (1) when consider the weighted than M5 alternatives was best, (2) when consider the unweighted than M4 alternatives was best [15].

- Advanced manufacturing technologies (AMT) is an important item in the design of a manufacturing system. In this paper, an analytic hierarchical process (AHP) based on fuzzy numbers multi-attribute method is proposed for the evaluation and justification of an advanced manufacturing system. Orlando Duran and Jose Aguilo [16] take three alternatives and six criteria. They applied above method on CNC turning machines and give the results that M3 alternatives was best [16].

- In this paper, the selection process of alternative determination of the importance weight of customer requirement with the help of AHP method. K D Maniya and N K Zaveri [17] take different water jet weaving machine attributes such as Cost, Maintenance, and Noise, Speed Production rate, Area requirement, Reed width and Power. It has concluded that the AHP method is adequate for complex evolution of water jet weaving machine alternative applying this method the best water jet weaving machine alternative will be selected and implemented [17].

III. METHODOLOGY: AXIOMATIC PRINCIPLES

Axioms are widely accepted principles, which are the fundamental concepts of this process. The first design axiom is known as the Independence Axiom and the second axiom is known as the Information Axiom. Axioms are general principles or self-evident truths that cannot be derived or proven true; however, they can be refuted by counterexamples or exceptions. They are stated as follows [6, 24].

Suh [6, 24] identified two design; the first axiom is called the Independence Axiom. It states that the independence of functional requirements (FRs) must be always maintained, where FRs are defined as the minimum set of independent functional requirements that characterize the design goals. The second axiom is called the Information Axiom, which states that among those designs that satisfy the Independence Axiom the design that has the highest probability of success is the best design. During the mapping process (for example, mapping from FRs in the functional domain to DPs in the physical domain), the designer should make correct design decisions using the Independence Axiom. When several designs that satisfy the Independence Axiom are available, the Information Axiom can be used to select the best design [6, 24].

A. The Information axiom:

When there is only one FR, the Independence Axiom is always satisfied, and the only task left is to optimize the given design. Various optimization techniques have been advanced to deal with optimization problems involving one objective function. However, when there are two or more FRs, some of these optimization techniques do not work. In these cases, we must first develop a design that is either uncoupled or decoupled. If the design is uncoupled, it can be seen that each FR can be satisfied and the optimum points can be found. If the design is decoupled, the optimization technique must follow a set sequence.

For a given set of FRs, it is most likely that every designer will come up with different designs, all of which are acceptable in terms of the Independence Axiom. However, one of these designs is likely to be the superior alternative. The Information Axiom provides a quantitative means for establishing the merits of a given design, and this value is used to select the best solution [6, 24].
The Information Axiom is the Minimize the information content. Information is defined in terms of the information content I that is related, in its simplest form, to the probability of satisfying a given set of FRs. If the probability of success is pi, the information content I associated with the probability is defined as,

$$\mathbf{I = -log_2\, p_i} \qquad (1)$$

Where $\mathbf{p_i}$ = (system range/common range)
Equation (1) defines information content in the units of binary digits or bits. In the general case of an uncoupled design with n FRs, I may be expressed as

$$\mathbf{I = -\sum_{i=1}^{n} log_2\, p_i = \sum_{i=1}^{n} I_i} \qquad (2)$$

Where pi is the probability of DPi satisfying FRi. Since there are n FRs, the total information content is the sum of all the individual measures. When all probabilities pi are equal to one, the information content is zero.

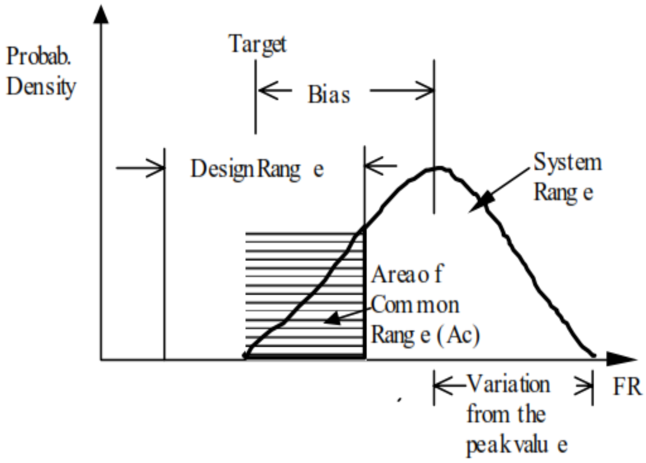


Figure 1. Design Range, System Range and Common Range [6]

Design Range, System Range, and Common Range in a plot of the probability density function (pdf) of a functional requirement. The deviation from the mean is equal to the square root of the variance. The design range is assumed to have a uniform probability distribution in determining the common range.
Conversely, the information content is infinite when one or more probabilities are equal to zero. A design is called complex when its probability of success is low. The quantitative measure for complexity is the information content: complex systems require more information to make the system function. Thus, a large system that is comprised of many subsystems and components is not necessarily complex. Even a small system can be complex if its probability of success is low.

IV. ILLUSTRATE EXAMPLE:

A. DEFINATION:

- Following criteria was selected as our requirement:
- FR_1 = Capital cost (CC) of CNC lathe is required between 800000 to 1300000 Rs.
- FR_2 = Spindle speed (SS) of CNC lathe is required between 4500 to 6000 rpm.
- FR_3 = Tool capacity of CNC lathe is required between is 8 to 12.
- FR_4 = Rapid traverse in X-axis (TX) of CNC lathe is required between 6 to 18 mm.
- FR_5 = Rapid traverse in Z-axis (TZ) of CNC lathe is required between 8 to 16 mm/min.
- FR_6 = Maximum machining diameter of CNC lathe is required between is 150 to 250 mm.
- FR_7 = Maximum machining length of CNC lathe is required between is 450 to 600 mm.

- Collected various CNC lathe machines data as following in table [8]

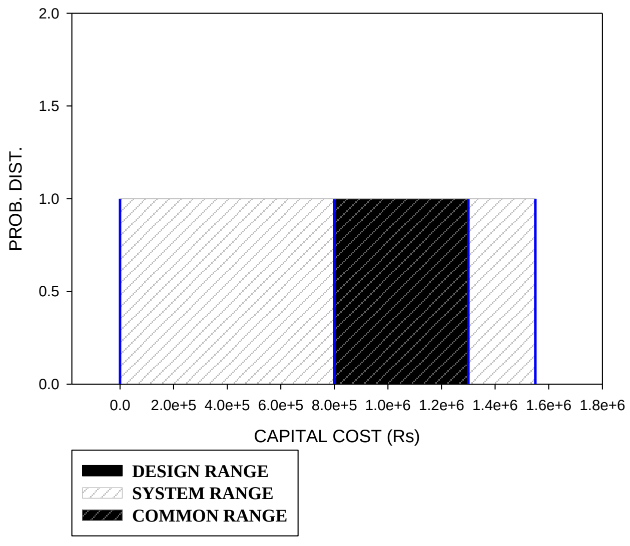
Table 1 Various CNC Lathe machines data

Sr. No.	Machine no.	CNC Lathe	CC	SS	TC	TX	TZ	MD	ML
1	M1	YANG ML-5A	0	0	0	0	0	0	0
			1200000	5590	8	24	24	205	350
2	M2	YANG ML-25A	0	0	0	0	0	0	0
			1550000	3465	8	20	20	280	520
3	M3	YCM TC-15	0	0	0	0	0	0	0
			1400000	5950	12	15	20	250	469
4	M4	VTURN 16	0	0	0	0	0	0	0
			1100000	5940	12	12	15	230	600
5	M5	FEMCO HL-15	0	0	0	0	0	0	0

			1200000	5940	12	12	16	150	330
6	M6	FEMCO WNCL-20	0	0	0	0	0	0	0
			1500000	3465	12	6	12	260	420
7	M7	FEMCO WNCL-30	0	0	0	0	0	0	0
			2600000	3960	12	12	16	300	625
8	M8	EX-106	0	0	0	0	0	0	0
			1320000	4950	12	24	30	240	340
9	M9	ECOCA SJ20	0	0	0	0	0	0	0
			1180000	4480	8	24	24	250	330
10	M10	ECOCA SJ25	0	0	0	0	0	0	0
			1550000	3950	12	15	20	280	460
11	M11	ECCOA SJ30	0	0	0	0	0	0	0
			1600000	3450	12	15	20	280	460
12	M12	TOPPER TNL-85A	0	0	0	0	0	0	0
			1200000	3465	8	20	24	264	400
13	M13	TOPPER TNL-100A	0	0	0	0	0	0	0
			1350000	2970	8	20	24	264	400
14	M14	TOPPER TNL-100AL	0	0	0	0	0	0	0
			1400000	2970	12	24	30	300	600
15	M15	TOPPER TNL-85T	0	0	0	0	0	0	0
			1350000	3465	12	30	30	264	350
16	M16	TOPPER TNL-100T	0	0	0	0	0	0	0
			1450000	2970	12	20	24	300	400
17	M17	TOPPERTNL-120T	0	0	0	0	0	0	0
			1520000	2475	12	20	24	300	400
18	M18	ATECH MT-52S	0	0	0	0	0	0	0
			1376000	4752	12	20	24	235	350
19	M19	ATECH MT-52L	0	0	0	0	0	0	0
			1440000	4752	12	20	24	235	600
20	M20	ATECH MT-75S	0	0	0	0	0	0	0
			1824000	3790	10	12	20	300	530
21	M21	ATECH MT-75L	0	0	0	0	0	0	0
			1920000	3790	10	12	20	300	1030

B. SOLUTION:

- From above information in table 1, we draw a graph of probability distribution vs FRs.
- In fig. 2 & 3, sample graphs generated and find the common range & system range.



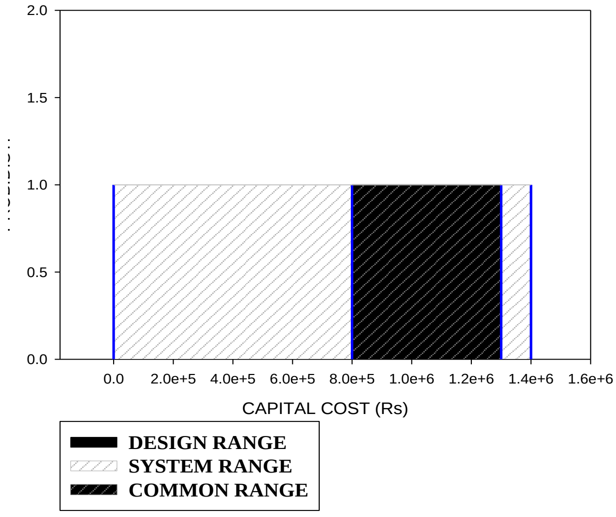


Figure 2 CAPITAL COST vs PROB. DIST. OF M2 & M10

Figure 3 CAPITAL COST vs PROB. DIST. OF M3 & M14

- System Range calculate from the above graphs as shown below.

$$SYSTEM\ RANGE = End\ Point - Start\ Point$$

$$= 1200000 - 0 = 1200000$$

- Using above calculation calculate all data as shown in table 2.

Table 2 System Range

Sr. No.	Lathe	CC	SS	TC	TX	TZ	MD	ML
1	M1	1200000	5590	8	24	24	205	350
2	M2	1550000	3465	8	20	20	280	520
3	M3	1400000	5950	12	15	20	250	469
4	M4	1100000	5940	12	12	15	230	600
5	M5	1200000	5940	12	12	16	150	330
6	M6	1500000	3465	12	6	12	260	420
7	M7	2600000	3960	12	12	16	300	625
8	M8	1320000	4950	12	24	30	240	340
9	M9	1180000	4480	8	24	24	250	330
10	M10	1550000	3950	12	15	20	280	460
11	M11	1600000	3450	12	15	20	280	460
12	M12	1200000	3465	8	20	24	264	400
13	M13	1350000	2970	8	20	24	264	400
14	M14	1400000	2970	12	24	30	300	600
15	M15	1350000	3465	12	30	30	264	350
16	M16	1450000	2970	12	20	24	300	400
17	M17	1520000	2475	12	20	24	300	400
18	M18	1376000	4752	12	20	24	235	350

19	M19	1440000	4752	12	20	24	235	600
20	M20	1824000	3790	10	12	20	300	530
21	M21	1920000	3790	10	12	20	300	1030

- Common Range calculate from the above graphs as shown below.

$$COMMAN.RANGE = 1200000 - 800000 = 400000$$

- Using above calculation calculate all data as shown in table 3.

Table 3 Common Range

Sr. No.	Lathe	CC	SS	TC	TX	TZ	MD	ML
1	M1	400000	2190	0	12	8	55	0
2	M2	500000	65	0	12	8	100	70
3	M3	500000	2550	4	9	8	100	19
4	M4	300000	2540	4	6	7	80	150
5	M5	400000	2540	4	6	8	0	0
6	M6	500000	65	4	0	4	100	0
7	M7	500000	560	4	6	8	100	150
8	M8	500000	1550	4	12	8	90	0
9	M9	380000	1080	0	12	8	100	0
10	M10	500000	550	4	9	8	100	10
11	M11	500000	50	4	9	8	100	10
12	M12	400000	65	0	12	8	100	0
13	M13	500000	0	0	12	8	100	0
14	M14	500000	0	4	12	8	100	150
15	M15	500000	65	4	12	8	100	0
16	M16	500000	0	4	12	8	100	0
17	M17	500000	0	4	12	8	100	0
18	M18	500000	1352	4	12	8	85	0
19	M19	500000	1352	4	12	8	85	150
20	M20	500000	390	2	4	8	100	80
21	M21	500000	390	2	4	8	100	150

- The information contents of table 2 and table 3 are computed using Eq. (1) and data shown in table 4 as below.

I=$\log_2(1/pi)$ =$\log_2$ (system range/common range)

$$= \frac{\log(\frac{SYSTEM.RANGE}{COMMON.RANGE})}{\log 2}$$

$$= \frac{\log(\frac{1200000}{400000})}{0.3010}$$

$$= 1.5850$$

➢ Now using above calculation we can find all data and show in below table 4.

Table 4Probability

Sr. No.	Lathe	CC	SS	TC	TX	TZ	MD	ML	TOTAL
1	M1	1.5850	1.3519	INFINITE	1.0000	1.5850	1.8981	INFINITE	**INFINITE**
2	M2	1.6323	5.7363	INFINITE	0.7370	1.3219	1.4854	2.8931	**INFINITE**
3	M3	1.4854	1.2224	1.5850	0.7370	1.3219	1.3219	4.6255	**12.2991**
4	M4	1.8745	1.2256	1.5850	1.0000	1.0995	1.5236	2.0000	**10.3082**
5	M5	1.5850	1.2256	1.5850	1.0000	1.0000	INFINITE	INFINITE	**INFINITE**
6	M6	1.5850	5.7363	1.5850	INFINITE	1.5850	1.3785	INFINITE	**INFINITE**
7	M7	2.3785	2.8220	1.5850	1.0000	1.0000	1.5850	2.0589	**12.4293**
8	M8	1.4005	1.6752	1.5850	1.0000	1.9069	1.4150	INFINITE	**INFINITE**
9	M9	1.6347	2.0525	INFINITE	1.0000	1.5850	1.3219	INFINITE	**INFINITE**
10	M10	1.6323	2.8443	1.5850	0.7370	1.3219	1.4854	5.5236	**15.1295**
11	M11	1.6781	6.1085	1.5850	0.7370	1.3219	1.4854	5.5236	**18.4394**
12	M12	1.5850	5.7363	INFINITE	0.7370	1.5850	1.4005	INFINITE	**INFINITE**
13	M13	1.4330	INFINITE	INFINITE	0.7370	1.5850	1.4005	INFINITE	**INFINITE**
14	M14	1.4854	INFINITE	1.5850	1.0000	1.9069	1.5850	2.0000	**INFINITE**
15	M15	1.4330	5.7363	1.5850	1.3219	1.9069	1.4005	INFINITE	**INFINITE**
16	M16	1.5361	INFINITE	1.5850	0.7370	1.5850	1.5850	INFINITE	**INFINITE**
17	M17	1.6041	INFINITE	1.5850	0.7370	1.5850	1.5850	INFINITE	**INFINITE**
18	M18	1.4605	1.8134	1.5850	0.7370	1.5850	1.4671	INFINITE	**INFINITE**
19	M19	1.5261	1.8134	1.5850	0.7370	1.5850	1.4671	2.0000	**10.7135**
20	M20	1.8671	3.2807	2.3219	1.5850	1.3219	1.5850	2.7279	**14.6895**
21	M21	1.9411	3.2807	2.3219	1.5850	1.3219	1.5850	2.7796	**14.8151**

V. CONCLUSION:

➢ For the illustrative shows the result in terms of probability, Table 4 shows the probability of various selection criteria at Table 1. From the Table 4, The information content of machine M1, M2, M5, M6, M8, M9, M11 to M18 infinite since it cannot satisfy FR2, FR3, FR4, FR6, FR7, i.e., the design range and the system range do not overlap at all.

- The information contents of machine M3, M4, M7, M10, M19, M20 and M21 are computed using Eq. (1) as shown in Table 4.

- **From above data, the machine M4 is best suited for our requirement which matches with the results as obtained by Sun [8] and Sankar Chakraborty [9, 10].** Here successfully applied Axiomatic Principles for selection the machines. Further, these principles can be apply for any selection of equipment, software, robots, manufacturing process, etc.

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