

Factors affecting human performance in lathe machine shop operations

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Abstract

This study helps to identify the factors, which affect human performance in lathe machine shop operations and adopt mitigation strategies. This study helps the practitioner to identify the critical factors that reduce human performance and occurrence of error during the operations. This paper illustrates the framework development of an Interpretive Structural Modelling for analysing the factors relating to human performance in lathe machine shops. The key issues related to human performance factors are discussed and interrelationship between the factors are analysed. The results indicate that noises, temperature in work place, shop floor practice are most crucial factors.

Keywords: Human Reliability; Human Error; Human Behavior; Human Factors; Work Systems.

1. Introduction

Human performance analysis and assessment process are an important aspect to make quick decisions by managers. The human actions, failure events, human behaviour type, incorrect outputs and error types are some of challenges which is identified and described by many researchers. But, very few study only analysed human performance factors in context of machine shops. In this paper we attempt to identify the factor which is related for human performance in lathe machine shops operations using Interpretive Structural Modelling (ISM) approach. This case study has been conducted in the selected lathe machine shops which are located in the Coimbatore city, India. The proposed framework will helps to practitioners to improve their machine shops operations.

2. Literature review

The literature has been reviewed two folds from the perspective of human factors related to machine shop operations and the application of interpretive structural modelling approach.

2.1. Human factors in operations

Bertolini (2007) [1] described as workload is a one of the major factor in human reliability assessment in operations. The amount of work assigned to the particular worker is a major performance assessment factor. Time pressure is another psychological stress factor in the work place (Bertolini, 2007[1]; Rasmussen, 1985[2]). Stress is the physical and emotional response factor in the work place. Skills are developed through adequate training and experience. Abilities are quality of work performed by worker (Jen-Gwo Chen, & Chen, 1996[3]). Unwanted noise and abnormal temperature will directly affect the human performance in the work place (Rasmussen, 1985[2]). Shop floor practices are one of the factor directly affects workers productivity. Safety practices will reduce

injury in the shop floor operations (Kosmowski, 1995 [4]; Gandhi and Gandhi, 2015 [5]). Administrative pressure will induce the human errors in the work systems (Kosmowski, 1995 [4]; Gandhi and Gandhi, 2015 [5]). Sleeping tendency in the workplace will reduce productivity and increase the injury rate (Jen-Gwo Chen, & Chen, 1996 [3]).

2.2 Applications of ISM approach

ISM approach is an interactive learning process and structural model. Saleeshya et al. (2012) [6] developed framework for agility assessment in supply chain network using ISM combined with analytic hierarchy process. Ambika Devi Amma et al. (2015) [7] applied ISM approach for analysing major threads of cloud computing. Sudharsan and Suresh (2016) [8] studied factors which related to solar lantern purchasing by street vendors using ISM. Venkatesh and Suresh (2016) [9] applied ISM for analysing factors which related to Indian tourism promotion through social media. Abinaya and Suresh (2016) [10] applied ISM for lean banking practices. Renganath and Suresh (2016) [11] applied ISM for analysing factors related to safety practices in Indian manufacturing company. Keerthana and Suresh (2016) [12] applied ISM to analyse lean factors in street food vending process. Amrita and Suresh (2016) [13] used ISM to study the lean practices in supermarket. Patri and Suresh (2017a) [14] applied ISM approach for analysing lean implementation factors in healthcare organisations. Patri and Suresh (2017b) [15] analysed agile factors in healthcare organisations using Total ISM.

3. Methodology

The following steps are used to illustrate the modelling procedures of ISM (Patri and Suresh, 2017a [14]):

- 1) Identification of factors through expert interview and literature survey. Table 1 depicts the identified human performance factors related to lathe machine shop operations.

- 2) Self-structured interaction matrix: Deriving a contextual relationship between the pair of factors which are mentioned below:

V: i influences j
 A: j influences i
 X: i and j influences each other
 O: J and I are not-related

The pair wise comparisons of factors are taken from opinions of 15 lathe machine operators (experts). The highest mode of opinion is selected from the opinions of all experts. The Self Structured Interaction Matrix (SSIM) derived from mode of opinions of each pair is depicted in Table 2.

- 3) Initial reachability matrix: The development of initial reachability matrix from SSIM and the conversion steps are mentioned below:

From SSIM (i,j) entry	V	A	X	O
To initial reachability matrix (i,j) entry	1	0	1	0
To initial reachability matrix (j,i) entry	0	1	1	0

The initial reachability matrix for human performance operations is shown in Table 3.

- 4) Final reachability matrix: Development of final reachability matrix from initial reachability matrix through transitivity analysis which follows that if A=B; B=C; then A=C. The final reachability matrix is shown in Table 4.
- 5) Partition of the final reachability matrix: Partitions of the final reachability matrix are mainly based on the three sets, i.e. reachability set, antecedent set and intersection set. Iteration-1, the intersection elements are only present in the reachability set, those enablers are removed from the set and designated as level-1 factors. Then go to next iteration, repeat the process until all the factors are removed from the set. At the end of this process we get partitioned reachability matrix in to different levels and it is depicted in Table 5, 6,7,8,9 and 10.

Table 1: Identified Factors on Human Performance

Sl. No.	Factor	Description	References
1	Work load (F1)	The amount of work or number of units assigned to particular individual over period of time.	[1];[2]
2	Time pressure (F2)	A type of psychological stress when a person has less time to available than is necessary to complete a task	[1];[2]
3	Stress (F3)	Stress is the harmful physical and emotional responses of a situation where individual affected	[3]; [16]
4	Skill and Ability (F4)	Skills and abilities of worker can be developed and improved by training in over a period time	[3];[16]
5	Noise (F5)	Noise means unwanted sound or loud discordant or disagreeable sound or sounds.	[2]
6	Temperature (F6)	Temperature at work is a health and safety issue for workers who work in the production unit.	[2]
7	Shop and Floor Practice (F7)	Shop and Floor Practice is an area on which work has to complete.	[4];[5];[2]
8	Safety Practice (F8)	A Safety practice is a form of 'administrative control' which helps to avoid the accidents in working area.	[4];[5];[2].
9	Administrative Pressure (F9)	Administrative Pressure is to establish standards for managers and staff to increase the performance.	[4];[5];[2].
10	Sleep (F10)	Sleeping while on duty or sleeping on the	[3];[16]

job refers	to falling
asleep while on the time clock.	

- 6) Digraph Creation: Directed graph (Digraph) is created using information from final reachability matrix and level partitions. In digraph factors are placed in ascending order i.e. first level factor at top of the digraph and second level factor at second position and so on until the lowest level factor is placed at the lowest level in the digraph. The ISM model is depicted in Figure 1.

Table 2: SSIM for Human Performance Factors

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	V	V	A	O	O	O	V	O	O
F2		1	V	O	O	O	O	O	O	O
F3			1	O	A	A	A	V	A	O
F4				1	O	O	O	O	O	A
F5					1	O	X	V	O	V
F6						1	X	V	O	O
F7							1	V	O	O
F8								1	X	A
F9									1	O
F10										1

Table 3: Initial Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	1	0	0	0	0	1	0	0
F2	0	1	1	0	0	0	0	0	0	0
F3	0	0	1	0	0	0	0	1	0	0
F4	1	0	0	1	0	0	0	0	0	0
F5	0	0	1	0	1	0	1	1	0	1
F6	0	0	1	0	0	1	1	1	0	0
F7	0	0	1	0	1	1	1	1	0	0
F8	0	0	0	0	0	0	0	1	1	0
F9	0	0	1	0	0	0	0	1	1	0
F10	0	0	0	1	0	0	0	1	0	1

Table 4: Final Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	1	1	1	0	0	0	0	1	1*	0
F2	0	1	1	0	0	0	0	1*	1**	0
F3	0	0	1	0	0	0	0	1	1*	0
F4	1	1*	1*	1	0	0	0	1*	1**	0
F5	1**	1***	1	1*	1	1*	1	1	1*	1
F6	1****	1*****	1	1***	1*	1	1	1	1*	1**
F7	1***	1****	1	1**	1	1	1	1	1*	1*
F8	0	0	1*	0	0	0	0	1	1	0
F9	0	0	1	0	0	0	0	1	1	0
F10	1*	1**	1**	1	0	0	0	1	1*	1

Table 5: Iteration-1 of Level Partition of Factors

Factor	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2,3,8,9	1,4,5,6,7,10	1	
2	2,3,8,9	1, 2,4,5,6,7,10	2	
3	3,8,9	1, 2,3,4,5,6,7,8,9,10	3,8,9	I
4	1, 2,3,4,8,9	4,5,6,7,10	4	
5	1,2,3,4,5,6,7, 8,9,10	5,6,7	5,6,7	
6	1,2,3,4,5,6,7,8,9, 10	5,6,7	5,6,7	
7	1,2,3,4,5,6,7,8,9,10	5,6,7	5,6,7	
8	3,8,9	1,2,3,4,5,6,7,8,9,10	3,8,9	I
9	3,8,9	1,2,3,4,5,6,7,8,9,10	3,8,9	I
10	1, 2,3,4,8,9,10	5,6,7,10	10	

Table 6: Iteration-2 of Level Partition of Factors

Factor	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 2	1,4,5,6,7,10	1	
2	2	1, 2,4,5,6,7,10	2	II
4	1, 2,4	4,5,6,7,10	4	
5	1, 2,4,5,6,7,10	5,6,7	5,6,7	
6	1, 2,4,5,6,7,10	5,6,7	5,6,7	
7	1, 2,4,5,6,7,10	5,6,7	5,6,7	
10	1, 2,4,10	5,6,7,10	10	

Table 7: Iteration-3 of Level Partition of Factors

Factor	Reachability Set	Antecedent Set	Intersection Set	Level
1	1	1,4,5,6,7,10	1	III
4	1, 4	4,5,6,7,10	4	
5	1, 4,5,6,7,10	5,6,7	5,6,7	
6	1, 4,5,6,7,10	5,6,7	5,6,7	
7	1, 4,5,6,7,10	5,6,7	5,6,7	
10	1, 4,10	5,6,7,10	10	

Table 8: Iteration-4 of Level Partition of Factors

Factor	Reachability Set	Antecedent Set	Intersection Set	Level
4	4	4,5,6,7,10	4	IV
5	4,5,6,7,10	5,6,7	5,6,7	
6	4,5,6,7,10	5,6,7	5,6,7	
7	4,5,6,7,10	5,6,7	5,6,7	
10	4,10	5,6,7,10	10	

Table 9: Iteration-5 of Level Partition of Factors

Factor	Reachability Set	Antecedent Set	Intersection Set	Level
5	5,6,7,10	5,6,7	5,6,7	
6	5,6,7,10	5,6,7	5,6,7	
7	5,6,7,10	5,6,7	5,6,7	
10	10	5,6,7,10	10	V

Table 10: Iteration-6 of Level Partition of Factors

Factor	Reachability Set	Antecedent Set	Intersection Set	Level
5	5,6,7,10	5,6,7	5,6,7	VI
6	5,6,7,10	5,6,7	5,6,7	VI
7	5,6,7,10	5,6,7	5,6,7	VI

4. Results and analysis

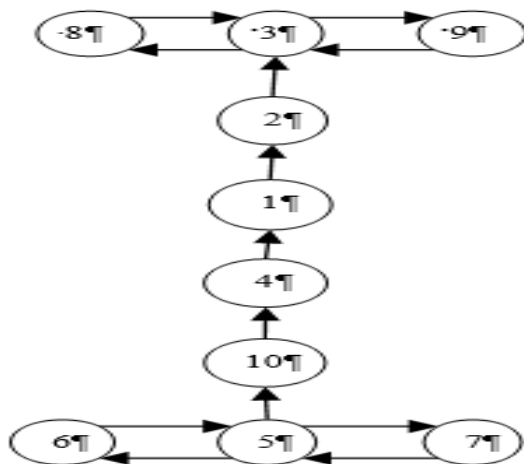


Fig. 1: ISM Model for Human Performance of Factors in Machine Shop Operations.

Level VI factors: [5] [6] and [7].

F5 influencing F3: The noisy atmosphere in the work will lead to stress among workers increased during the long day of work. Sometimes workers get irritated due to high noise and their mind set will change on working.

F5 influencing F7: The noisy atmosphere increases the stress level of the worker which will lead the worker to alter the shop floor culture followed by the administration.

F5 influencing F8: The continuous noise makes the workers ear drum to damage in long run, so workers are strictly to adopt safety measures during the working time.

F5 influencing F10: Due to the continuous noise created by the machines in the work area may affect the sleep of workers, which reduce the sleeping duration. The next day work also been affected

F6 influencing F1: The temperature of the work place influences the workload of each worker. The workers feel to complete the work in regular temperature and the work varies according to the temperature.

F6 influencing F2: When the temperature is high the worker will not be able to do normal work in regular timing, so that will increase the time pressure to finish the work.

F6 influencing F3: When the temperature is normal the stress level of the worker will be normal once the temperature increases the stress level of the worker will also increase which will affect the work.

F6 influencing F7: Temperature affects the working condition. Employees should always be made to work in a good atmosphere or else it may affect the productivity of the company.

F6 influencing F10: When the worker is working in a hot temperature his sleep is affected and that affects the normal sleep, which also affect the working nature.

F7 influencing F1: The shop floor culture affects the workload given to employees. Good Shop floor culture always makes the workload to be less for employees.

F7 influencing F3: Shop floor culture will influence the stress level. A strict hierarchy will also add more stress to the workers.

F7 influencing F8: When the shop floor culture is not maintained will lead to accident, so safety precaution should be carried by administration in the workplace.

Level V factors: 10

F10 influencing F1: When the worker does not sleep well and he is having so much work load then the job will be not finished on time so that the work will be splatted among other workers to avoid the quality damage made by the single worker.

F10 influencing F4: When the worker does not get a proper sleep he may not be able to concentrate on the work. The workers can lose his ability and skill to continue the work.

Level IV factors: [4]

F4 influencing F1: The skill and ability of the worker is influenced by workload, when the work load is less he will be more conscious on the work and will finish it in good manner. If the work is more workers will have the intention to finish the work which will alter his skills

F4 influencing F2: The skill and ability of the worker may alter based on the time pressure, but a good worker will be able to manage the work.

F4 influencing F3: The skill and ability of the worker is influenced the stress level because when he does any mistake his skill gets down and which will mentally increase the stress level.

F4 influencing F8: The ability of the worker to follow the safety rules may alter the culture of the safety in the company.

Level III factors: [1]

F1 influencing F2: When the workload is high the workers feel the time pressure to complete the work on time. They will plan accordingly and split the work among the workers to finish it before time.

F1 influencing F3: When the work load increases the working time gets increased and will have the pressure to finish the work on time, which will make the workers feel stressed.

F1 influencing F8: Workers safety is very important element in workplace, when the workload is more the worker looks for the safety measures to avoid accidents that may occur during work.

Level II factors: [2]

F2 influencing F3: When the time pressure increases we need to be more conscious on the product. The time pressure leads the workers to stress on a long run.

F2 influencing F8: During the time pressure worker needs to be more focused on the safety accepts which may lead to accidents if the precaution measures are not taken

F2 influencing F9: During the time pressure the administration pressure also increases which will make them to improve the skills and improving their strategies.

Level I factors [3], 8 and 9

F3 influencing F8: Workers due to extreme stress of work may forget to follow the safety rules which may lead to accidents.

F3 influencing F9: The stress level on workers may cause them to stand against the administrative rules which may lead to pressure in administration.

F8 influencing F3: When the safety is not followed in the shop floor then the stress level of the worker will be increased.

F8 influencing F9: The safety resolves the issues associated with administrative pressure because safety plays important role when the work is more.

F9 influencing F3: The administrative pressure strives to develop negative result because when the plan does not match the worker's ability and time then stress level increased. The work routine is affected due to increase in stress among workers.

F9 influencing F8: When the workers are imposed with administrative pressures then worker will do work in a hurry which will lead to accidents if he/she does not follow safety aspects.

5. MICMAC analysis

MICMAC analysis is the cross-impact matrix multiplication applied to classification and it's an operational method. MICMAC rank helps to classify the identified factors based on their driving power and dependence power. In this MICMAC analysis, the variables involved in the study are classified broadly into four categories viz. autonomous factors, dependent factors, linkage factors, independent factors and corresponding MICMAC graph is presented in Figure 2.

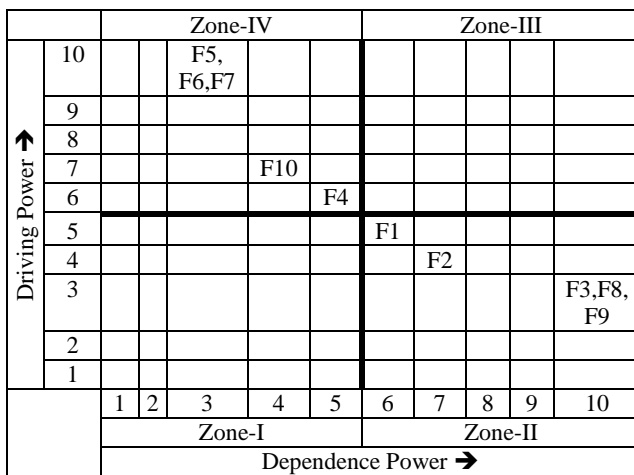


Fig. 2: MICMAC Graph.

From the MICMAC graph, the following factors F1, F2, F3, F8, F9 are dependent factors in zone-II, and F4, F5, F6, F7, F10 are independent factors in zone-IV. In this analysis noise, temperature and shop and floor practice are key factors, which directly influence the human performance in the lathe machine shop operations. Table 11 represents the MICMAC rank of the study where Rank 1 corresponds to the most crucial factors and Rank 6 corresponds to the least important factors among all.

Table 11: MICMAC Analysis of Factors Rank

Factor	Driving power	Dependence power	Driving power / Dependence power	MICMAC rank
F1	5	6	0.833	4
F2	4	7	0.572	5
F3	3	10	0.3	6
F4	6	5	1.2	3
F5	10	3	3.333	1
F6	10	3	3.333	1
F7	10	3	3.333	1
F8	3	10	0.3	6
F9	3	10	0.3	6
F10	7	4	1.75	2

6. Conclusion

The skills and ability of the worker is a main factor for producing a quality product in an industry. The product produced with high quality can be achieved by reducing work pressure and work load

among workers. The administration should provide full safety and neat to carryout work in a workplace among workers. The noisy atmosphere at workplace can lead to health issues of workers, which is rectified by providing safety measures to workers and administration should impose the workers to follow. The temperature in the workplace makes a difference in working nature of workers, so during hot climate the worker should be given a space to relax himself and work during his working hours. The shop floor should be maintained neat and 5S could be followed by the administration to identify safety issues easily. The sleep is one of the important factors for the worker when the sleep is disturbed or altered the end result is lack of performance during production. So the worker should be given rest and we should make sure they have given average hour of sleeping time.

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