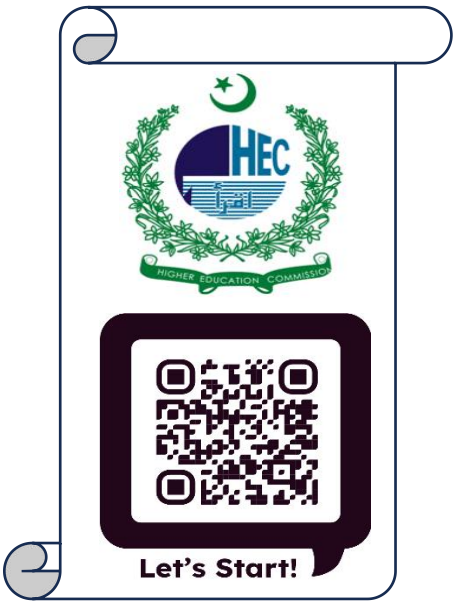
Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

Policy Journal of Social Science Review



An Initial Indigenous Comparative Analysis of Cognitive Assessment Tools for Cognitive Load Measurement of Workforce in Industry 4.0 Era

Muhammad Ammar Masood Cheema[1]
Sibgha Farooqi[2]
Mishal Zoha[3]
Muhammad Talha Khalid[4*]

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

An Initial Indigenous Comparative Analysis of Cognitive Assessment Tools for Cognitive Load Measurement of Workforce in Industry 4.0 Era

Muhammad Ammar Masood Cheema	GIFT Business School, GIFT University
Sibgha Farooqi	Department of Humanities and Social Sciences, GIFT University
Mishal Zoha	Department of Humanities and Social Sciences, GIFT University
Muhammad Talha Khalid	Department of Humanities and Social Sciences, GIFT University. Corresponding author email: hss.hod@gift.edu.pk

Abstract

With the evolution of industry, the way of working has changed dramatically around the globe. The focus is shifted to consider physical load and cognitive load simultaneously. And to assess cognitive load multiple tools have been used to assess the cognitive load (CL) i.e. performance based, physiological measures and subjective measures. However, in this article, the last one has been discussed. Three popular tools have been carried away named Subjective Work Load Assessment Method (SWAT), NASA Task Load Index (NASA-TLX), and Cognitive Load Assessment Method (CLAM). On the basis of the results, it is quite evident that CLAM has a well-defined range of components to measure cognitive load which helps to do better cognitive load management. All these three tests have almost similar factors but CLAM has the advantage that it also describes CL caused by the work station design or orientation while SWAT's main focus seems to be on the psychological and effort whereas NASA-TLX has batter significance while consider the physical and temperamental demand of the task which also have impact on the CL of a person.

Keywords: Cognitive Load, SWAT, NASA-TLX, & CLAM, Industry 4.0, Digitalization, CPPS

INTRODUCTION

Since the existence of this world, the main focus of every world is around to measure the efficiency of the work (Hooijberg, & Watkins, 2022). While talking about industry, we have seen that since the beginning to industrial revolution the main focus is how to measure the efficiency of an industrial system effectively (Yang, Zou, Shang, Ye, & Rani, 2023). After the first industrial revolution which is Industry 1.0 often one operator employed to run a production system using electromechanical dials and move from machine to machine to get the data. In industry 2.0 the

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

concept of separate control rooms with large control parameters were applied (Sassanelli, Taisch, & Terzi, 2023).

The workload of factory operators has shifted from physical load to mental workload due to successive industrial revolutions and increasing complexity of data and information communication technology in factory automation (Kumar & Kumar, 2019). From the electromechanical dials that are locally attached to machine in industry 1.0, only single has been selected to supervise complete production system. However, due to industry 2.0 it becomes possible to monitor all the production process through isolated control rooms (Sassanelli, Taisch, & Terzi, 2023). Even the large control penal with separate sections for machine parameters can be diagnosed with multiple separate operators. On the other hand, the type 3.0 industry has amalgamated both production operations and computer-based manufacturing besides using robots for supervising production process remotely.

With the evolution of industry 4.0, the concept of smart factory evolved in which cyber-physical production system (CPPS) emerged. This type of industrial revolution has brought internet of things (IoT) to monitor human-computer interaction system (Hussain, 2020). Hence, multidisciplinary solution is required with the ample knowledge gathered from cognitive psychology, operation management, data science, industrial design, manufacturing technology, and instrumentation engineering in order to address the issues related to optimal design of control in CPPSs.

As the industry grow the efficiency measurement method also changed their focus on some more important term. We used to measure the efficiency in factories by using OEE (Overall Equipment Efficiency), OME (Overall Material Effectiveness) and OLE (Overall Labor Effectiveness) but due to increase in the complexity of procedures and use of IT the cognitive load factor has shown remarkable change since the beginning of industrial revolution (Kumar, Singh, & Dwivedi, 2020).

Cognitive load is the ability of an individual human being to take load of instruction on his working memory. According John Sweller (1988) who was the first person in 1988 described that there are three types of cognitive loads, Extrinsic load means the way new information presented to the worker, intrinsic load means the fundamental difficulty in the topic despite how well you presented it will stay and Germane load means how the you create the mantle scheme for something new.

In this article we try to do a comparative study to measure the CL by using three different subjective assessment methods.

COGNITIVE LOAD MEASUREMENT METHODS

After going through some literature review, we have found out that there were four subjective assessment methods between which we did comparative study to find Cognitive load through following three methods.

- SWAT (Subjective Workload Assessments Technique) (Luximon, & Goonetilleke, 2001).
- NASA-TLX (Task Load Index) (Stanton, Salmon, & Walker, et al. 2005).

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

- CLAM (Cognitive Load assessment Method)-Specially Designed for the manufacturing industries (Thorvald, Lindblom, & Cort, 2017).

SWAT (SUBJECTIVE WORK LOAD ASSESSMENT METHOD)

This method is developed in to measure cognitive load in subjective manner three dimensions has been decided to follow like Time Load, Mental effort load, psychological stress load. Theses dimensions are derived from the definition of cognitive load defined by Sheridan and Simpson (1979).

The SWAT is two-step process in which first step is called scale development in this we find out all the possible combinations of three dimensions we have taken and they are 27 in total. Each operator sorts the cards into the rank order according to his/her perception of workload. For example, a card with the combination 1, 1, 1 for the time load, mental effort and psychological stress would means lowest workload. While card score of 3, 3, 3 means the maximum workload.

The second step is the event scoring which is the actual rating of workload for a given task. This activity is much easier and an individual assessment of the task. Subject are asked to rate the specific task with regard time load, metal effort load and psychological stress load dimensions (e.g. 1, 3, and 1).

The scale value associated with this combination (which is obtained from the scaled development in the first step) is then assigned a value for that activity expressed as numeric score between 0 100. As shown in figure1.

Event	Event Rating	SWAT Scale Card Combination	SWAT Scale Rescaled Value
1	2-2-1	111	0.0
2	2-1-3	112	24.4
3	1-1-1	113	51.4
4	3-1-2	121	7.6
5	1-3-3	122	32.0
6	2-3-1	123	59.0
7	2-1-2	131	27.7
8	1-2-2	132	52.1
9	3-3-3	133	79.1
10	3-2-1	211	6.5
		212	30.9
		213	57.9
		221	14.1
		222	38.5
		223	65.5
		231	34.2
		233	85.6
		311	20.9
		312	45.2
		313	72.3
		321	28.5
		322	52.9
		323	79.9
		331	48.6
		332	73.0
		333	100.0

The result generates and do analysis (Luximon, & Goonetilleke, 2001).

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

TABLE 1: ***SCALE MEASUREMENTS OF SWAT***

		Scale measurement
1.	<20	Very Low
2.	20- 40	Low Cognitive load
3.	40-60	Moderate Cognitive load
4.	>60	High Cognitive load

NASA-TLX (NASA-TASK LOAD INDEX)

To assess the subjective mental work load (MWL), NASA task Load Index is one of the most widely used tools in organizational settings. It allows the researcher to assess the mental load of the worker while performing task. This index assesses the worker's performance on six domains namely,

- Mental demand: the amount and level of cognitive effort required in performing a certain task.
- Physical demand: the physical effort required in a task.
- Temporal demand: handling the time stress involved in performing a certain task.
- Effort: the hard work required in maintaining a certain level of performance.
- Performance: success required in the completion of task.
- Frustration: the stress and discouragement or vice versa a worker feels while completing the task.

With reference to the application of the tool, each of the above-mentioned subscale is presented to the research participant and he/she is asked to rate on an interval scale ranging 1-20 where 1 represents the lowest and 20 represents the highest (Stanton, Salmon, & Walker, et al. 2005).

TABLE 2: ***SCALE MEASUREMENTS OF NASA-TLX***

		Scale Measurement
1.	<20	Very Low
2.	20- 40	Low Cognitive load
3.	40-60	Moderate Cognitive load
4.	>60	High Cognitive load

CLAM (COGNITIVE LOAD ASSESSMENT METHOD)

It's a subjective method to measure the cognitive load in specially manufacturing industries as the all-other methods are not specialized rather generic in nature. So, in 2017 a group of students has developed this scale for the basic purpose to cater the manufacturing industries. The Clam tool consists of following factors

- **Saturation**- the balance of assembly task
- **Variant flora**-the estimation of level of variation of products on the workstation
- **Production awareness**-An assessment on how much focused attention must be applied to the task
- **Difficulty of tool use**-relates to the amount of tool use and its subjective complexity

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

- **Number of tools used**-the number of tools used.
- **Mapping of workstation**-the correspondence between workstation layout and assembly sequence
- **Part identification**-more cognitively easily part identification
- **Information cost**-how much physical or cognitive effort that is required to utilize the information i.e. if information is easily assessable or not.
- **Quality of Instruction**-the general quality of the instructions used to gather information about the work based on HCI principles.
- **Poke-a-yoke**-the presences or absence of poke-a-yoke solutions or other types of constraints.

All these parameters have given range of options in the form of levels you have to select the appropriate level to get the result. The instruction to use this tool are provided in annexure. This is Excel base software package which can produce immediate result after getting input values (Thorvald, Lindblom, & Cort, 2017).

TABLE 3: ***SCALE MEASUREMENTS OF CLAM***

		Scale Measurement
1.	<2	Very Low
2.	2- 4	Low Cognitive load
3.	4-6	Moderate Cognitive load
4.	>6	High Cognitive load

METHODOLOGY

Two industries were selected with one task from each industry and applied theses three subjective measurement methods to measure CL.

STEP 1: Select the Industry
STEP 2: Define the Task
STEP 3: Select the sample
STEP 4: Perform the task
STEP 5: Measure the CL using
a. SWAT (Subjective Workload Measurement Technique)
b. NASA-TLX (Task load Index)
c. CLAM (Cognitive Load Assessment Method)
STEP 6: Compile the result
STEP 7: Perform Comparative study
STEP 8: Write Conclusion.

EXPLANATION

Following is an explanation of the above-mentioned steps.

STEP 1: SELECTION OF INDUSTRY

According to available literature there are three types of industries primary, secondary and territory

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

Primary industries are those which deals with natural resources.
Secondary industries are those which use output of the primary industries and convert them into useful products like all the manufacturing industries.
Tertiary industries are those which provides services in to support other industries like banking, schools and hospitals etc.
Here we have selected secondary and tertiary industry and perform these subjective measurement methods for the Cognitive load.
Industry 1: Café truck (a food preparing truck)
Industry 2: GIFT University

STEP 2: SELECTION AND EXPLANATION OF THE TASK

We have selected one task from each of the two industries.

INDUSTRY 1(SECONDARY INDUSTRY):

The task we have selected from this industry was making of tea from coffee machine.

TABLE 4: ***INDUSTRY 1 CAFÉ TRUCK: TEA MAKING TASK DESCRIPTION***

Task name	**Tea Making**	
S/No	**Sub Task Name**	**Duration**
1	Turn On Tea Making Machine	10 sec
2	Check the material levels	1 min
3	If levels down refill otherwise okay	2 min
4	Take order receipt	3 min
5	Put Cup under the tea pouring point	10 sec
6	Select the ordered option and press the button to start	10 sec
7	After tea filled put lid on cup	10 sec
8	Deliver to customer	10 sec

INDUSTRY 2 (TERTIARY INDUSTRY)

From this industry we have selected the task of delivering the lecture of 1.5 hrs., to the humanities department

TABLE 5: ***INDUSTRY 2 GIFT UNIVERSITY: LECTURER DELIVERING TASK DESCRIPTION***

Task name	**Lecture Delivery**	
S/No	**Sub Task Name**	**Duration**
1	Topic section	10 min
2	PPT slides Preparation	60 min
3	Word Document preparation	20 min
4	Reach the Class on time	10 min
5	Mark the Attendance	10 min
6	Deliver the lecture	70 min
7	Take Questions	10 min
8	Uploading slides on digital forum	5 min

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

STEP 3: SELECT THE SAMPLE

We have selected the sample for the both tasks

a) INDUSTRY 1(SECONDARY INDUSTRY)

The sample selected for this task was as follow

TABLE 6: *DEMOGRAPHIC INFORMATION OF INDUSTRY 1 SAMPLE*

Name	Nature Of Job	Education	Age	Demographic
Sample	Senior Worker	Pre-Graduation	23	Gujranwala

b) INDUSTRY 2 (TERTIARY INDUSTRY)

The sample selected for this task was as follow

TABLE 7: *DEMOGRAPHIC INFORMATION OF INDUSTRY 2 SAMPLE*

Name	Nature Of Job	Education	Age	Demographic
Sample	Lecturer	Post-Graduation	30	Gujranwala

STEP 4: PERFORM THE TASK

a) Industry 1(Secondary Industry):

TABLE 8: *INDUSTRY 1'S PERFORMANCE ON SWAT*

TASK	**TEA making**			
TEST name	**SWAT (Subjective Work load Assessment Technique)**			
	TIME load	**Effort**	**Psychological Stress**	**Result**
Sample	3	1	2	45.12

TABLE 9: *INDUSTRY 1'S PERFORMANCE ON NASA-TLX*

TASK	**TEA making**						
TEST name	**NASA- TLX (Task Load Index)**						
	Mental Demand	**Physical Demand**	**Temporal Demand**	**Performance**	**Effort**	**Frustration**	**Result**
Sample	High	Low	High	High	Less	High	58.2 %

TABLE 10: *INDUSTRY 1'S PERFORMANCE ON CLAM*

TASK	**TEA making**					
TEST name	**CLAM (Task Related)**					
	Saturation	**Variant flora**	**Level of difficulty**	**Difficulty of tool use**	**Production Awareness**	**Result**
Sample	2	8	4	5	4	4.82

TEST name	**CLAM (Workstation Related)**					
	No of Tools Available	**Mapping**	**Parts Identification**	**Information Cost**	**Quality of Instruction**	**Poka-A-Yoke**
Sample	2	2	6	4	2	8

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

b) INDUSTRY 2 (TERTIARY INDUSTRY)

TABLE 11: ***INDUSTRY 2'S PERFORMANCE ON SWAT***

TASK	**Lecture delivery of 1.5 hrs.**			
TEST name	**SWAT (Subjective Work load Assessment Technique)**			
	TIME load	**Effort**	**Psychological Stress**	**Result**
Sample	3	2	2	52.9

TABLE 12: ***INDUSTRY 2'S PERFORMANCE ON NASA-TLX***

TASK	**Lecture delivery of 1.5 hrs.**					
TEST name	**NASA- TLX (Task Load Index)**					
	Mental Demand	**Physical Demand**	**Temporal Demand**	**Performance**	**Effort**	**Frustration**
Sample	High	High	High	High	High	High

TABLE 13: ***INDUSTRY 2'S PERFORMANCE ON CLAM***

TASK	**Lecture delivery of 1.5 hrs.**					
TEST name	**CLAM**					
	Task Related					
	Saturation	**Variant flora**	**Level of difficulty**	**Difficulty of tool use**	**Production Awareness**	**Result**
Sample	2	0	7	6	6	4.95
	Workstation Related					
Task Name	**No of Tools Available**	**Mapping**	**Parts Identification**	**Information Cost**	**Quality of Instruction**	**Poka-A-Yoke**
Sample	1	7	0	6	6	8

STEP 6: RESULTS

Since the beginning of industrial revolution, the focus is to understand as well as to assess the not only the physical load but also the cognitive load (Hooijberg, & Watkins, 2022). And to assess the later one, a decent number of tools has been used. In general, these tools can be classified into three categories i.e. performance based, physiological measures and subjective measures (Rubio, Díaz, Martín, & Puente, 2004). In this paper, the last one has been discussed.

A comparison of three popular tools has been carried away named SWAT, NASA-TLX, and CLAM. On the bases of the results, it is quite evident that CLAM has a well-defined range of components to measure cognitive load which helps to do better cognitive load management. Each component is divided into two main groups named work station related cognitive load measurement and task related cognitive load measurement (Thorvald, Lindblom, & Cort, 2017). Initial work in this domain focused only on the physical load, but in the recent times the focus shifted on the cognitive load of the workers as well (Hooijberg, & Watkins, 2022). As now it has been an established fact that cognitive load is not affected by task only but also the work station/ work place orientation matters quite significantly.

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

We have taken two different forms of industries from manufacturing to service providing. It is evident from the result the measuring of cognitive load is almost similar like moderate cognitive load. Now after going through three different CL measuring Subjective methods, it's quite evident in terms of load the results are almost similar but in terms of details each tool has its own specific domain

TABLE 14: ***RESULTS COMPARISON OF SWAT, NASA-TLX AND CLAM***

	Results		
S/NO	**Café Truck**	**Delivering the Lecture in Gift Uni.**	**Scale measurement description**
SWAT	45.12	52.9	Moderate CL
NASA-TLX	58.25	62.0	Moderate CL
CLAM	4.82	4.95	Moderate CL

DISCUSSION

As the results are showing that the outcomes of all three tools are similar but the tables below can show that CLAM provide in-depth assessment. If we have to focus on stress and physical demand which is quite common in-service industries, we can see that SWAT and TLX is more relevant but if you have to use the manufacturing industries then the CLAM has more significance because its division of content is well define and relative to the need of question.

All these three tests have almost similar factors but CLAM has the advantage that it also describes CL caused by the work station design or orientation while SWAT's main focus seems to be on the psychological and effort whereas NASA-TLX has batter significance while consider the physical and temperamental demand of the task which also have impact on the CL of a person.

IMPLICATIONS

The article provides the base for further studies in this sector. It also provides base for better worker allocation. Moreover, it may help in measuring cognitive load in well-defined manner indigenously.

SUGGESTIONS

Demographics i.e. age, gender, education and further demographics should be explored in detail. Future researcher may increase the strength of sample in order to establish psychometric properties of tools indigenously. An effort can be made to establish an indigenous tool to measure physical and cognitive load while keeping local issues in consideration.

REFERENCES

Hooijberg, R. & Watkins, M. (2022). The Future Workplace Depends on Efficiency,Effectiveness, and Balance. *MIT Sloan Management Review Logo*. https://sloanreview.mit.edu/article/the-future-workplace-depends-on-efficiency-effectiveness-and-balance/#

Hussain, A. (2020). Industrial revolution 4.0: implication to libraries and librarians. Library hi tech news, 37(1), 1-5. https://doi.org/10.1108/LHTN-05-2019-0033

Kumar, N., & Kumar, J. (2019). Efficiency 4.0 for Industry 4.0. *Human Technology, 15*(1), 55. DOI:10.17011/ht/urn.201902201608

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 3 No. 2 (2025)

Kumar, R., Singh, R. K., & Dwivedi, Y. K. (2020). Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges. *Journal of cleaner production, 275*, 124063. https://doi.org/10.1016/j.jclepro.2020.124063

Luximon, A. & Goonetilleke, R.S. (2001). Simplified subjective workload assessment technique. Ergonomics. DOI: 10.1080/00140130010000901

Rubio, S., Díaz, E., Martín, J., & Puente, J. M. (2004). Evaluation of subjective mental workload: A comparison of SWAT, NASA-TLX, and workload profile methods. *Applied psychology*, *53*(1), 61-86. https://iaap-journals.onlinelibrary.wiley.com/doi/full/10.1111/j.1464-597.2004.00161.x

Sassanelli, C., Taisch, M., & Terzi, S. (2023). History and Future of Manufacturing. In Advances in Digital Manufacturing Systems: Technologies, Business Models, and Adoption. *Singapore: Springer Nature Singapore*. https://link.springer.com/chapter/10.1007/978-981-19-7071-9_2

Sherwani, F., Asad, M. M., & Ibrahim, B. S. K. K. (2020). Collaborative robots and industrial revolution 4.0 (ir 4.0). *International Conference on Emerging Trends in Smart Technologies (ICETST).* 1-5. DOI: 10.1109/ICETST49965.2020.9080724

Stanton, N., Salmon, P., Walker, G., et al. (2005). Mental workload assessment method. Human factors methods: a practical guide for engineering and design. *Great Britain: Ashgate*. 301-64. https://digital.ahrq.gov/health-it-tools-and-resources/evaluation-resources/workflow-assessment-health-it-toolkit/all-workflow-tools/nasa-task-load-index

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12,* 2, 257-285. https://doi.org/10.1016/0364-0213(88)90023-7

Thorvald, P. Lindblom, J., & Cort, R. (2017). CLAM - A method for cognitive load assessment in manufacturing. Robotics and Computer-Integrated Manufacturing. 114-119. https://www.researchgate.net/publication/323640203_CLAM_A_method_for_cognitive_load_assessment_in_manufacturing

Yang, L., Zou, H., Shang, C., Ye, X., & Rani, P. (2023). Adoption of information and digital technologies for sustainable smart manufacturing systems for industry 4.0 in small, medium, and micro enterprises (SMMEs). *Technological Forecasting and Social Change, 188*, 122308. https://doi.org/10.1016/j.techfore.2022.122308