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Proposal for Work study 2.0: Accounting for Information Load

Kong Fansen (kongfs@jlu.edu.cn)
Jilin University

Original Article

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Abstract

Workers at production sites bear two types of loads: physical loads and information loads. With the progress made in science and technology—particularly information technology—and the increased levels of automation of production equipment, the proportion of physical loads borne by workers has decreased. Traditional work study is based on the research conducted by Frederick W. Taylor. However, in this study, a method for conducting work study, called “Work Study 2.0”, is proposed, which considers the information of a production site. Work Study 2.0 incorporates information flow/field analyses based on traditional work study. Work operational complexity and cognitive complexity measurements are used to analyse and improve information elements in the production site to reduce the information processing load borne by the workers. Finally, a case study employing the proposed method is presented. The results indicate that the proposed method can further ease the labour of the workers in a lean production system. Overall, this study enriches the theoretical system of the work study and provides a new theoretical tool for lean improvement and visual management.Workers at production sites bear two types of loads: physical loads and information loads. With the progress made in science and technology—particularly information technology—and the increased levels of automation of production equipment, the proportion of physical loads borne by workers has decreased. Traditional work study is based on the research conducted by Frederick W. Taylor. However, in this study, a method for conducting work study, called “Work Study 2.0”, is proposed, which considers the information of a production site. Work Study 2.0 incorporates information flow/field analyses based on traditional work study. Work operational complexity and cognitive complexity measurements are used to analyse and improve information elements in the production site to reduce the information processing load borne by the workers. Finally, a case study employing the proposed method is presented. The results indicate that the proposed method can further ease the labour of the workers in a lean production system. Overall, this study enriches the theoretical system of the work study and provides a new theoretical tool for lean improvement and visual management.

1. Introduction

As the fourth industrial revolution is gradually approaching, industry 4.0 is increasingly being promoted as the key to improving productivity, promoting economic growth, and ensuring the sustainability of manufacturing companies. Kolberg pointed out that methods and principles of lean production have become the major concepts to create highly efficient processes since the early 1990s[1]. Work study is still successful as the basic tool of lean improvement because it focuses on value-adding tasks. Nevertheless, the flexibility of the lean production method in the production of customised products is limited. Industry 4.0 describes the vision of smart production which can meet these future market requirements through innovative information and communication technologies and the integration of all production entities into a common digital network. Lean automation involves the application of Industry 4.0 technologies to lean production methods to combine benefits from both domains. Rosin studied the links between the principles and tools proposed as Industry 4.0 and as the Lean management approach, with a particular focus on the improvement effect of some Industry 4.0 technologies on the implementation of lean principles[2]. The results of Rosin strongly support Industry 4.0 technologies for Just-in-time and Jidoka schemes but not for waste reduction and People and Team work schemes.

For the use of industry 4.0 technologies and methods, a large amount of information is required, which increases the so-called cognitive load to worker, hindering their productivity improvement. However, as the main tool of lean production site improvement, traditional work study cannot solve this issue. The work study methods at present are still based on concepts from Taylor's era, i.e. reducing physical load and improving labour efficiency, and ignore the study on the information problems that affect the production efficiency, such as insufficient or redundant information and information load stress [4]. To solve this issue, in this study, we propose a new work study method that considers the information of production sites and measurements of operational complexity. The method, called 'work study 2.0' extends the original work study method to meet the demand of continuous improvement of the productivity in the information age.

The content of this paper is accompanied by illustrations of the case study conducted. The remainder of this paper is organised as follows. The general concept and development history of Work Study is introduced in Section 2. The Work Study 2.0 framework in the field of production improvement is developed in Section 3, considering the use of the information processing economy principle as an example. In Section 4, to maintain the integrity and self-inclusiveness of the article, an important concept of Work Study 2.0, the information processing economic principle, is briefly introduced. Further, the application of the proposed method is briefly discussed with respect to the field improvement, considering the economic principle of information processing as an example. The study is concluded in Section 5 with suggestions for future work.

2. Theoretical Background

The Industrial Revolution has drastically changed the world. This change increasingly involved the mechanisation and automation of work, which in turn required changes in business management. Frederick W. Taylor was the first to recognise the importance of work study. According to Taylor's research, to effectively complete work, you have to pinpoint the associated tasks, determine the most effective manner to realise them, and give yourself the necessary time. In this regard, Taylor recognised the importance of optimising working methods and the need for time study.

Similar to Taylor, Gilbreth systematically studied work. Gilbreth and his wife, Dr. Lillian Moeller Gilbreth, published *Fatigue Study* in 1916 and *Applied Motion Study* in 1917. Therein, their approach was different from that taken by Taylor. Gilbreth and Lillian focus on the best practices and work plan design rather than on high performance. They proposed a theory: All human motion can be reduced to 17 basic elements of motion. Their theory provides the theoretical basis for MTMs. To achieve optimal working methods in terms of execution, productivity, and performance, Gilbreth and Lillian eliminated every Therblig that hinders work.

When Segur published his work in 1926 under the title Motion Time Analysis, he developed the first predetermined time system (PTS). Until the 1930s, this system was used in most U.S. industries, followed by a series of more advanced PTS systems, such as a motion time survey, established by Joseph H. Quick in 1934, and a work factor method.In 1940, H. B. Maynard studied complicated work processes for drills. Along with L. John, Schwab, and Gustave J. Tegemerten, he designed a system that became the most successful process for optimising workflow globally: method-time measurement[5].

H. B. Maynard, J. L. Schwab, and G. J. Stegemerten worked to develop data that supported the basic methods of MTM. Over the next few years, the data were evaluated, revised, and thoroughly tested. The findings were published in 1948 in the journal *Factory Management and Maintenance*. In the same year, the book, *Method-Time Measurement*, was published, which outlined the basics of MTM methodology. In 1966, G. C. Heyde developed Modular Arrangement of Predetermined Time Standards (MODAPTS) based on MTM, which is the most concise method to integrate time and action in PTS technology. This IE method is widely used for factory improvement[6].

Maynard et al. have been working on the MTM approach. Although the original MTM standard time values were refined and extended, subsequent research did not add anything new to these values except marginal modifications, and they remain unchanged thus far. However, the use of MTM provides an effective basis for productivity assessment, which considers human capabilities and provides support for identifying defects in manual processes[7].

With the approach of the Fourth Industrial Revolution and the improvement of informatisation and automation, changes need to be incorporated at the work areas of enterprises. At present, the academia mainly describes these changes from the following two perspectives:

First, these changes are described in terms of automation. As Becker and Stern [8] stated, the two major changes to future production workspaces can be summarised as follows. First, humans are absolutely necessary in the future factory. There will be fewer manufacturing jobs because of automation; however, new jobs will be created around machines. Second, the new tasks will be more complex; the increasing complexity of products and processes as well as the need to interact with computational automation equipment will make human work tasks more complex. While automation reduces the physical load on workers, it also increases the complexity of systems because automation systems are highly integrated with current products, processes, information, resources, human tasks, and organisations. Automation may make the task of an operator; however, simultaneously, it adds complexity to systems that must be managed, maintained, redesigned, etc[9].

Fast Berglund et al. describes the above changes using levels of automation (LoA) cognition, which he believes can improve the working environment of operators and reduce their workload[10, 11,12,13,14,15]. The definition of LoA used in this paper is proposed by Frohm[15\6] as ‘the allocation of physical and cognitive tasks between humans and technology, described as a continuum ranging from totally manual to totally automatic’. The LoA for mechanical activities is referred to as mechanical LoA, while the LoA for cognitive activities is called information LoA.

Second, the changes to be incorporated at enterprises can be describe from the perspective of operators. With the evolution of technology with time, the relationship between man and machine in production has also changed.

Gorecky, Schmitt, Loskyll, and Zühlke [17], Romero, Noran, Stahre, Bernus, and Fast-Berglund[18], Romero, Stahre, et al. [19], Romero, Bernus et al.[20] describe these changes in terms of the technical assistance under which the operator completes the mission. The details are described as follows:

Operators manually operating a machine tool with the aid of a mechanical tool are defined as Operators 1.0; those working with computer support, Operators 2.0; those working cooperatively with the assistance of a robot or other equipment, Operators 3.0; those representing the “operator of the future” or an intelligent and skilled operator who, when needed, is assisted by machines to perform work, Operators 4.0. According to the type of skills augmentation, the Iveta Zolotová et al. divided Operator 4.0 into eight typologies. And they showed the feasibility of the Operator 4.0 concept in the laboratory environment by case study[21].

This paper attempts to describe these changes from the perspective of work study. Traditional work study is based on Taylor’s research, that is, to reduce physical load and improve labour efficiency; further, the relationship between operating time and methods is studied. According to the development of automation and information technology, we believe that the physical load borne by workers is gradually decreasing, while the information load is continuously increasing. However, the current work research methods neglect the research on information problems that affect production efficiency, such as insufficient or redundant information and information load pressure.

MTM visual inspection (developed in 1990) is the basic approach for planning, designing, and evaluating the time required for visual inspection activities, which are dependent on human judgement and decision making. However, the time required for these activities is the result of highly complex psychological processes. Therefore, they cannot be reliably analysed by the usual time calculation techniques. They still require the sight and time of the operators. Further, neither did they consider the requirements of modern information and communication technologies, nor did they fully consider the characteristics or performance capabilities of the operator [22].

Fässberg et al. [10] and Fast Berglund et al. [13] stated that, as the main tool for lean production site improvement, traditional work study cannot solve this problem. By contrast, the increasing automation and strict quality constraints associated with the manufacturing process are making the job of the operators increasingly difficult. With the rapid development of network and information technology, the information load of staff is constantly increasing. To enable workers to complete the given field tasks more effectively and ensure the effectiveness and efficiency of operators, correct information should be provided to the right people at the right time.

With regard to information and complexity in the manufacturing process, as stated by A. Claeys et al.[23], several manufacturing enterprises are faced with the problem of unrealistic and inefficient workshop information display. The concept of complexity involves two dimensions: uncertainty and time.

Uncertainty may be owing to the lack of information and/or the nature of the interaction among the system components and time-dependent decisions and operations.

In an assembly context, cognitive automation can support decision making to ensure error-free products are produced. The assembly task is still realised by humans and is, for the most part, entirely dependent on their own experience. Because of the product and operation complexity brought by the mixed model structure, the mental workload imposed on the operators is generally very high. Therefore, the probability of error is high, and delays may occur.

Romero[18] and Philipp Hold[22] believe that assembly and man-machine cooperation processes entail complexity, which is caused by insufficient information and increases cognitive load. Therefore, digital assistant systems can provide information support to reduce the corresponding complexity and cognitive load.

Several researchers are aware of the information and complexity problems faced by manufacturing field operators in the Information Age, and thus, have presented solutions. For instance, J. Abonyi[24] proposed a modular operator support system for multi-product processes. Tan Jeffrey Too Chuan [25] established a framework for assembly information development from task modelling to support man-machine collaboration in cell production. Philipp Hold[22] stated that digital information can assist humans in their work by creating working systems that remain flexible to changing products and unstable demands through human adaptation, while still utilising the potential to realise cost-effectiveness in future production scenarios. Fast Berglund [14,15] stated that the strategy of cognitive automation will become increasingly important for companies. Sonja Stork [26] believes that workers have various sources of information and must rapidly switch between different tasks during manual assembly tasks. The complexity of task execution can be reduced by proper information presentation and planning of work steps. First, note that bootstraps can support information processing during work, while reducing search time and accelerating assembly execution. Second, as multiple possible assembly sequences exist for a product, the optimal sequence for a single assembly step should be determined and the interference of previous task steps minimised. The solution to all the above-mentioned problems is to provide various support systems. This paper enriches the connotation of work study from the perspective of methodology. The improvement methods and basic principles for improving the output of manufacturing system are provided from the perspective of information study and complexity measurement. In the past, the content regarding work study was limited to humans, machines, and materials.

This paper states that the correct configuration of the production site information system, from the information source/accommodation channel to the optimal configuration of the information field, can solve the complexity problem and reduce the information load borne by workers (First, the information is insufficient, which requires more time to process; second, too much information exists, and more time is needed to extract effective information.). Improving labour productivity and product qualification rate is crucial. Although literature advocates the use of various digital support systems to solve the above problems, we believe that even the use of digital support systems should be based on the in-depth analysis of the information field and that flow and source/location of the production site should be effective, otherwise it will increase additional complexity and information load. Therefore, based on traditional work study, we have discussed information research and complexity measurement and defined the new work research method as “Work Study 2.0”, which expands the connotation of the original work study method to satisfy the demand of the continuous development of productivity in the Information Age.

3. Proposal Of Work Study 2.0

Production systems involve material, resource, and information flows, as shown in Fig. 1. They comprise different equipment for processing, testing, and storage and entail human intervention. In these systems, the inputs are various raw materials, and the outputs are the finished products. Unlike machine systems, which are connected physically, equipment is connected by information flows. For example, the movement of raw materials along the process direction is connected by the drive of a Kanban system [27], which conveys information between processes and automatically orders parts as they are used up. Every item or box of items that flows through the production line carries its own Kanban. Kanban displays can broadcast various information, from stock levels to production volumes. In its simplest form, a Kanban board shows the incoming goods, goods under production, and outgoing goods. In addition, the system is equipped with information including instructions and environment and safety information. The above-mentioned system elements are basic requirements of a production system, and the components of the production system are jointly determined by the super system interacting or co-existing with the production system, such as air (with characteristics of humidity and temperature) and lighting subsystems. The actual product quality and performance output of the production system are related not only to the interaction between the system components, but also to the super system elements, e.g. environmental factors.

The efficiency of a production system is considerably affected by the information elements in the system. For example, insufficient information and poor information transmission will lead to a decrease in the production system efficiency. A considerable amount of redundant information will significantly increase the information load, and consequently, reduce the productivity of workers [28]. In this study, we regard the production site as an information field and use the terms of information theory to define the elements in the production information field, as shown in Fig. 1.

(1) Channel: This contains various information systems (such as the manufacturing execution system, safety systems, and material flow-driven information systems) and various information transmission channels. In general, industrial off-the-shelf IT systems are not directly suited for the information flow from and towards the operator[29].

(2) Information source: This includes standard operation instructions (work instructions (WIs)), environmental safety information, quality information for the detection of early issues, equipment failure information, and safety warning information.

(3) Information sink: This includes information for workers, including information about the machines and materials.

(4) Information elements in the supersystem: Information elements include mobile phones, and the information includes time and weather information.

To ensure the rationality of interactive activities in the production site, the change of information requires that the information for the qualified operator be cognitive, and the input of operator’s activities to the “field” and the impact of the change of “field” on the operator’s behaviour must be perceived to a certain extent. Further, to ensure the effectiveness and efficiency of the operator, the right information should be provided at the right moment to the right person. Therefore, the process of information exchange should be carefully designed considering the elements of the information, choice of opportunity, and object and means of expression.

Fig. 2 shows the knowledge system framework of Work Study 2.0, which includes information study and complexity measurements. This framework considers the current development of automation technologies and the information load.

The method study aims to reduce unnecessary processes and improve labour productivity through process or operation analyses. The operation analysis aims to reduce unnecessary operations through a human–machine process analysis, while a motion analysis further refines the operations through a Therbligs analysis and improves the large-scale operation efficiency. The process analysis, which is a primary content of method study, involves the monitoring of the whole production process and a large-scale integrated analysis. Method study is a macro-to-microscopic study of human–machine operation based on principles of motion economy[30] (Heap, 2015). Work measurement provides several benefits to organisations because they can reduce labour costs, increase the overall productivity, and improve the supervision of future staff. Time study is one of the work measurement techniques. This study is a structured process that involves the direct observation and measurement of human work to establish the time required for the completion of a task while working at a defined level of performance.

Information study is divided into an information field analysis, a channel analysis, and information source and sink analyses and is also a macro-to-microscopic analysis process; information field, channel, and information source and sink analyses are macro, meso, and micro analysis processes, respectively. Macro and meso analysis processes mainly involve the field and flow analyses. Information technology reform simplifies the information channel and improves the information transmission efficiency. The main information flow analyses are the flow analysis and function analysis in TRIZ (The Theory of Inventive Problem Solving 40 Inventive Principles with Examples) and the field building and evolution analyses. The purpose is to analyse how the information field is configured such that the information flowing to the operator is neither more nor less. Micro information source designs, such as WI, warning, logo, and design, are used to improve the efficiency of information presentation, which is based on principles of the information processing economy proposed by Kong[3]. Åsa Fasth[11] studied the evolution of assembly instructions from the perspective of cognitive automation; however, his objective was to realise cognitive support, while the present study aims to improve the WIs.

The complexity measurement includes the operational complexity and cognitive complexity measurements. Work complexity measurements provide a complete measurement method for information study similar to the work measurement for method study. The proposed method uses the framework proposed by Kong[3] for the evaluation of the operational and cognitive complexities. The following illustrates the application of the Work Study 2.0 framework in the field of production improvement, considering the use of the information processing economy principle as an example.

4. Improvement Cases Based On Principles Of Information Processing Economy

In this section, we explain how to use information processing economy principles to improve methods, environment/safety, and measurements. These improvements are realised to reduce the workers' information load. To maintain the integrity and self-inclusiveness of the article, an important concept of Work Study 2.0, the information processing economic principle proposed by Kong[3], is briefly discussed.

(1) To reduce the information load, e.g. WIs, the maximum amount of disposable information should be implemented, in accordance with the 7 ± 2 principle suggested by Miller[31] in 1956. Miller claimed that the information processing capacity of young adults is around seven elements, which he called "chunks", irrespective of whether the elements are digits, letters, words, or other units.

(2) The depth of information processing should be reduced. For instance, the information processing depth of a digital dial indicator reading is less than that of a dial indicator because the measurement result can be directly seen on the digital indicator.

(3) Audio-visual information should be presented at the same time. For instance, it is better to simultaneously see and hear warnings from an Andon system in a lean job shop.

(4) The level of relaxed work should be assessed, e.g. using digital assistance systems.

4.1 Improvement related to the WI

(1 *Reducing the amount of information*

To reduce the amount of information, we consider the following steps. First, we sort out the information and delete repetitive and redundant information. Second, similar or ideologically similar information should be integrated, according to the logic of human thinking such that a clear and targeted information block can be produced. The number of information blocks should be between five and nine chunks. Finally, the layout of the information block is planned to be aesthetically pleasant and clear.

Following the above steps, we obtain our improvement plan, as shown in Figs. 3 and 4. Information is organised by blocks and similar information is combined into a block, which is convenient for users to use and watch, and the layout of the information blocks is re-planned. The whole WI is divided into seven blocks. In each small block, the 7 ± 2 principle is followed to determine the amount of information.

(2) *Reducing the depth of information processing*

We represent text as a combination of pictures and text and change the information processing and understanding process from “reading the text” to “analyse the picture”, as shown in Fig. 5. This is done to obtain information for the user in the process of using the WI, thereby reducing the depth of information processing.

To further improve the effectiveness of the WIs, we transform the image and text in the form of image and oral explanation by using a display screen to present the operation method to the user through video. This enables the user to obtain information without prior training by relying on the perception ability of the brain, rather than learning. However, this further improvement scheme makes use of the two principles of information processing economy—the reduction in the depth of information processing and facilitation of relaxed work.

4.2 Improvement related to environment and safety

To solve the problem of unclear expressions of environment and safety information, we propose the simultaneous presentation of audio-visual/audio and perceptual information in accordance with the principle of information processing economy. Fig. 6 shows a heat-sensitive wallpaper. When the indoor temperature reaches 30°, the flowers in the wallpaper become visible, prompting people to switch on the air conditioning.

Fig. 7 shows an elevator arrival prompt system with simultaneous audio-visual information. When we wait for the elevator in the lift lobby, the arrival of the elevator is generally accompanied by sound and light, which enables us to easily determine which elevator has arrived.

4.3 Improvement related to measurement methods/instruments

As shown in Fig. 8, the depth of information processing can be greatly reduced by selecting different measuring tools, e.g. length measuring tools, or reasonably improving the measuring methods.

Another case is ring part detection, as shown in Fig. 9. We use the principle of relaxed work from the economic principle of information processing to improve the measurement method. Our improvement plan is to test the rings by using special testing tools. If the ring parts cannot pass through the fixture, they satisfy the production requirement.

5. Conclusion

In this study, a work study method called Work Study 2.0 was proposed, and its feasibility was validated. This method involves improved methods, environment/safety, and measurements. Through a case study, we demonstrated that the research results of this paper can be widely used in the lean improvement and visual management tools' design of production sites. In addition, the results of this paper can facilitate the development of various operation support systems. However, this paper only provides an improvement case based on the economic principle of information processing. The research on how to improve the system efficiency by changing production process through information study will be provided in the follow-up study.

Declarations

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Availability of data and materials

The datasets supporting the conclusions of this article are included within the article.

Authors' contributions

The author' contributions are as follows: ** was in charge of the whole trial; ** wrote the manuscript; ** assisted with sampling and laboratory analyses.

Competing interests

The authors declare no competing financial interests.

Consent for publication

Not applicable

Ethics approval and consent to participate

Not applicable

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Figures

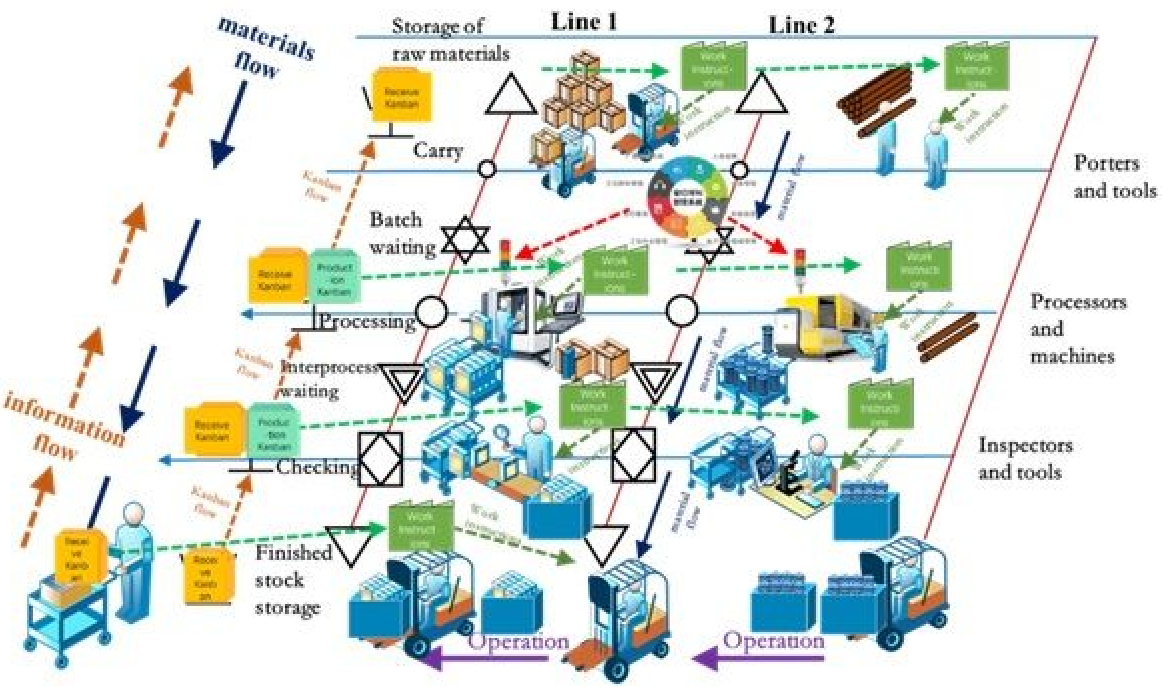


Figure 1

Information field in a production site

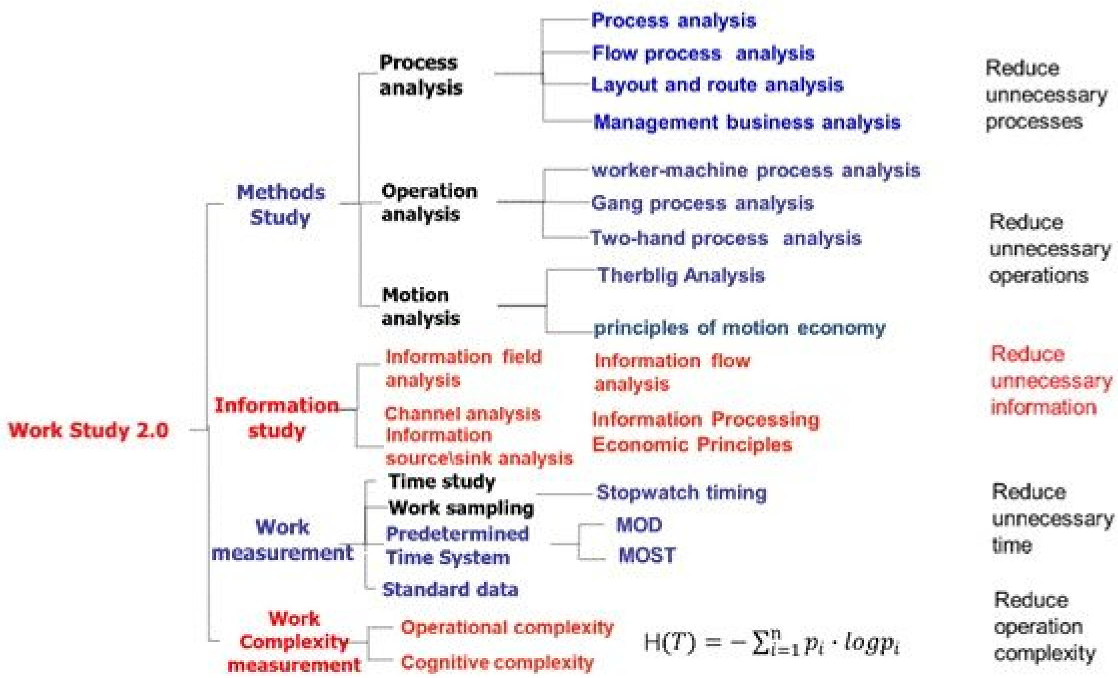
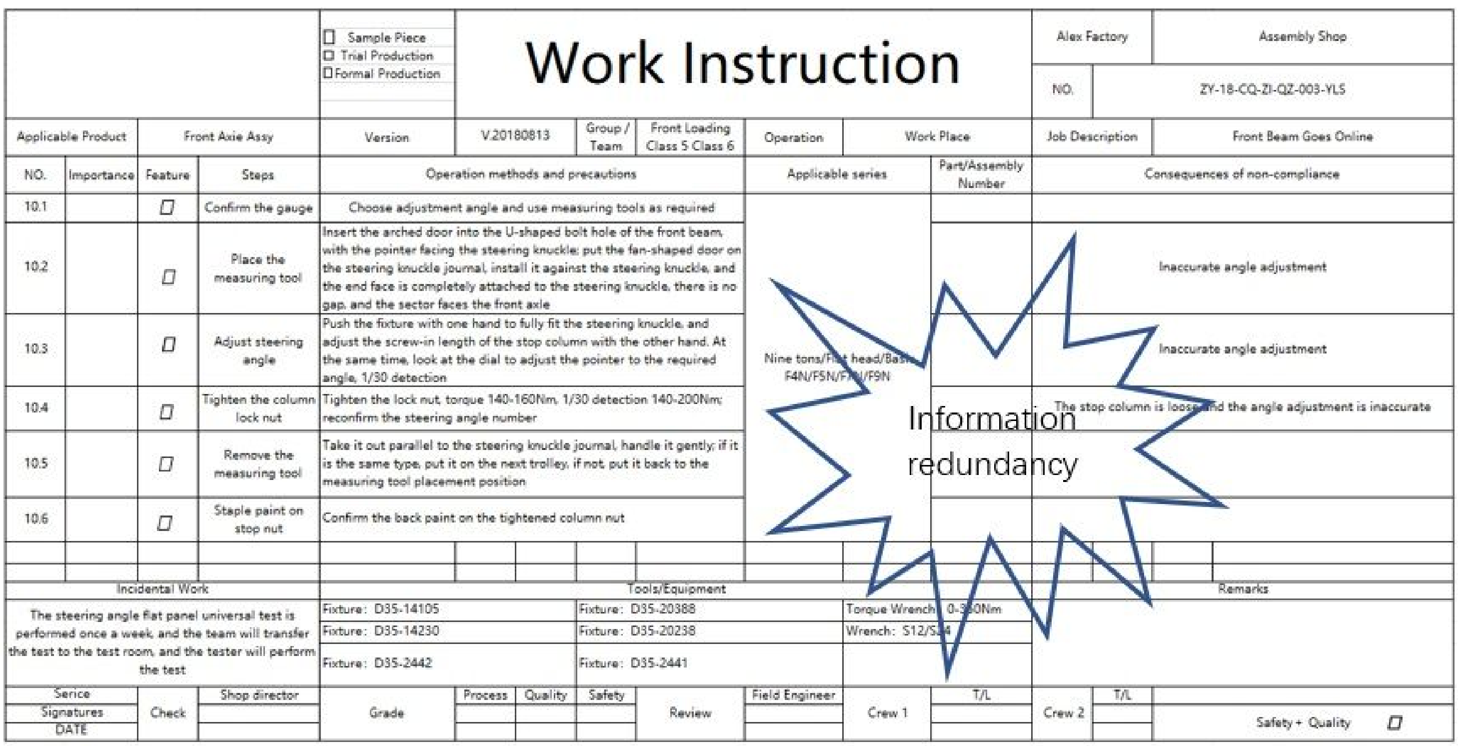


Figure 2

Knowledge framework of work study 2.0



□ Sample Piece
□ Trial Production
□ Formal Production

Work Instruction

Alex Factory	Assembly Shop	NO.	ZY-18-CQ-ZI-QZ-003-YLS
Applicable Product	Front Axle Assy	Version	V.20180813
Group / Team	Front Loading Class 5 Class 6	Operation	Work Place
Job Description	Front Beam Goes Online		

NO.	Importance	Feature	Steps	Operation methods and precautions	Applicable series	Part/Assembly Number	Consequences of non-compliance
10.1		□	Confirm the gauge	Choose adjustment angle and use measuring tools as required	Nine tons/[illegible] head/Bas[illegible] F4N/F5N/F[illegible]/F9N		
10.2		□	Place the measuring tool	Insert the arched door into the U-shaped bolt hole of the front beam, with the pointer facing the steering knuckle; put the fan-shaped door on the steering knuckle journal, install it against the steering knuckle, and the end face is completely attached to the steering knuckle, there is no gap, and the sector faces the front axle			Inaccurate angle adjustment
10.3		□	Adjust steering angle	Push the fixture with one hand to fully fit the steering knuckle, and adjust the screw-in length of the stop column with the other hand. At the same time, look at the dial to adjust the pointer to the required angle, 1/30 detection			Inaccurate angle adjustment
10.4		□	Tighten the column lock nut	Tighten the lock nut, torque 140-160Nm, 1/30 detection 140-200Nm; reconfirm the steering angle number			The stop column is loose [illegible] the angle adjustment is inaccurate
10.5		□	Remove the measuring tool	Take it out parallel to the steering knuckle journal, handle it gently; if it is the same type, put it on the next trolley, if not, put it back to the measuring tool placement position			
10.6		□	Staple paint on stop nut	Confirm the back paint on the tightened column nut			

Incidental Work	Tools/Equipment			Remarks
The steering angle flat panel universal test is performed once a week, and the team will transfer the test to the test room, and the tester will perform the test	Fixture: D35-14105	Fixture: D35-20388	Torque Wrench 0-[illegible]Nm	
	Fixture: D35-14230	Fixture: D35-20238	Wrench: S12/S[illegible]	
	Fixture: D35-2442	Fixture: D35-2441		

Serice Signatures DATE	Check	Shop director	Grade	Process	Quality	Safety	Review	Field Engineer	Crew 1	T/L	Crew 2	T/L	Safety + Quality □

Figure 3

WI before improvement

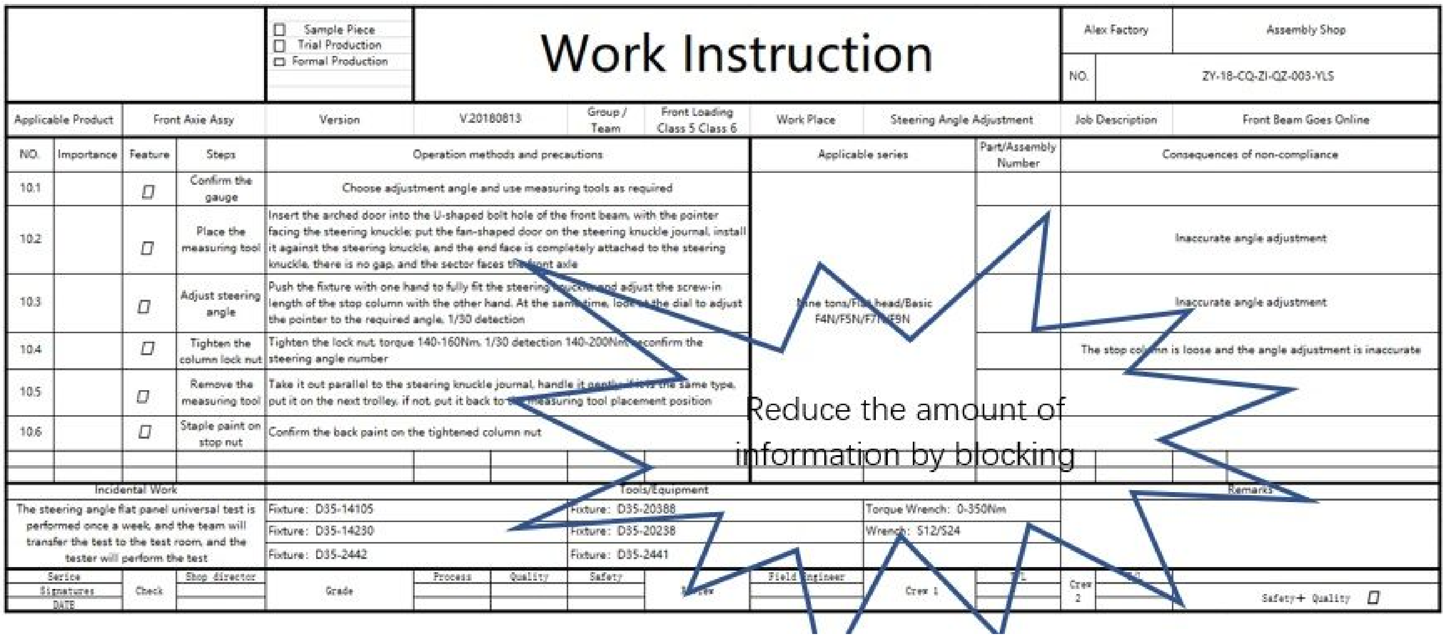


Figure 4

Improved WI based on the principle of reducing the amount of information

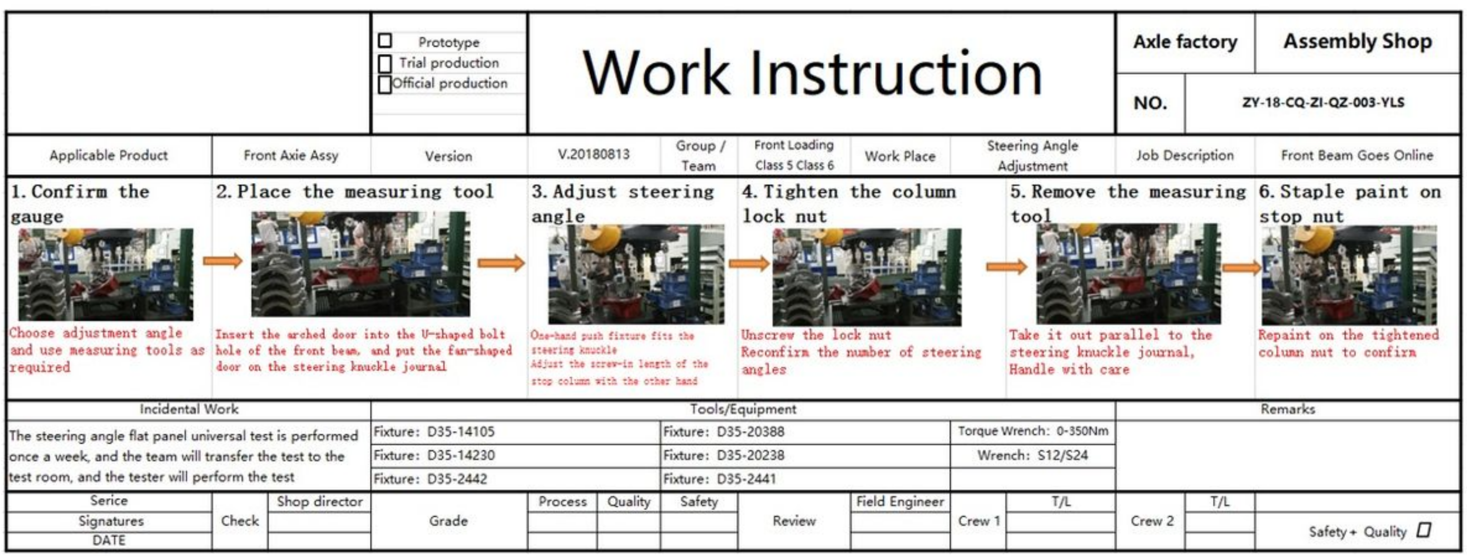


Figure 5

Improvement process of the WI by reducing information processing depth

(a) Temperatures below 30 degrees (b)Temperatures above 30 degrees

Figure 6

Simultaneous presentation of visual and sensory information (MAInD Staff. 2008; cited in 2010)

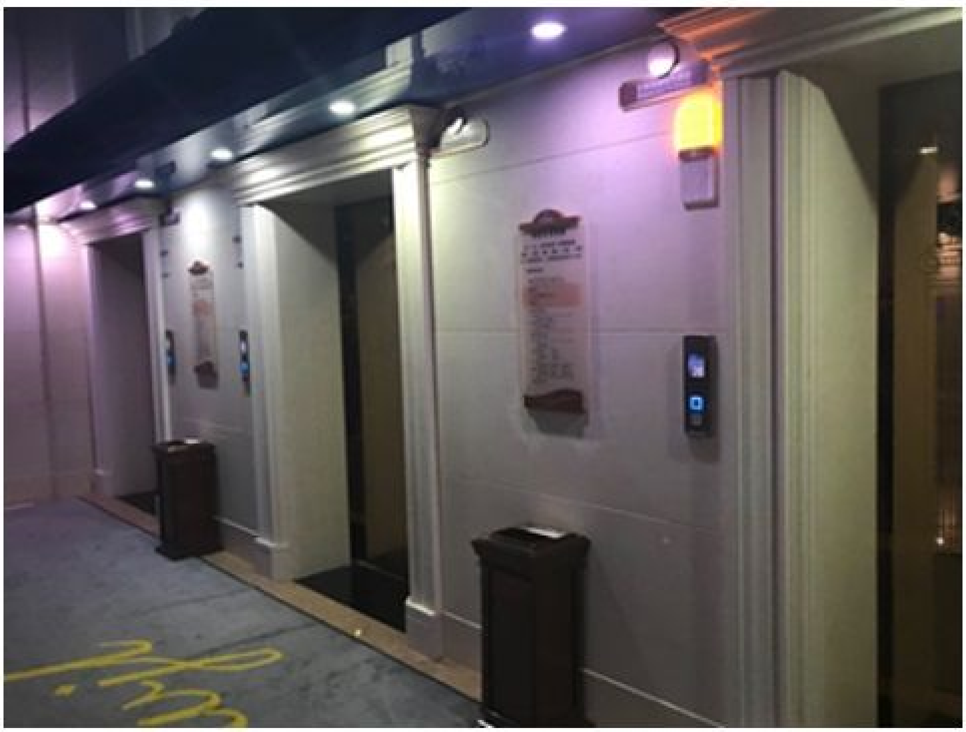


Figure 7

Simultaneous presentation of visual and auditory information

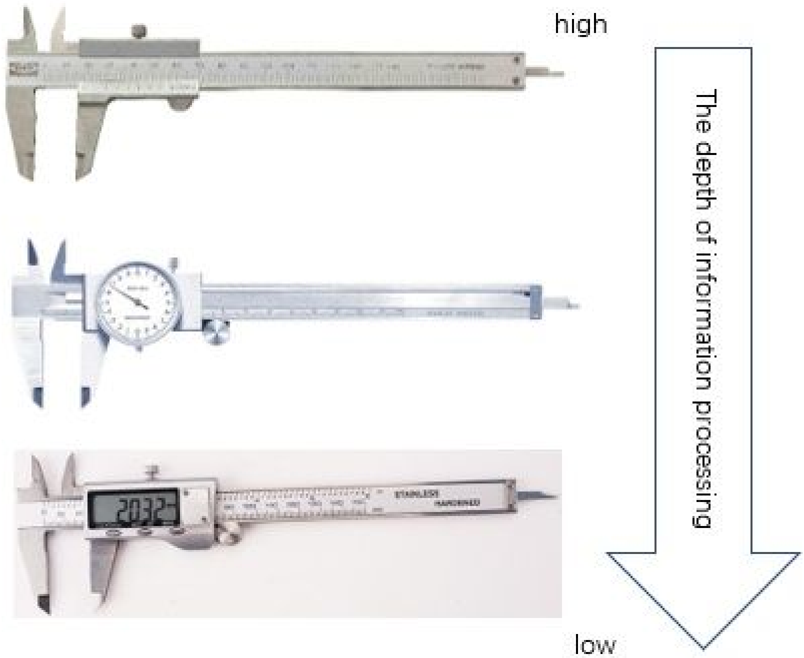


Figure 8

Schematic of length measurement tool selection

Figure 9

Ring part inspection reduces information processing depth