Research on the application of MOD method, the core technology of industrial engineering

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Abstract. This paper studies the application of MOD scheduled action time standard method. The Modular Arrangement of Determined Time Standards is abbreviated as MODAPTS method. MODAPTS job determination method is widely used in human factor engineering. This method decomposes job actions into 21 basic human body actions. When its time unit is MOD, each action has a corresponding standard time. In this paper, the application of MODAPTS method is systematically discussed, from its characteristic to the basic system of MODAPTS and the mark of motifs, with emphasis on the application of time value of time-limited action and simultaneous action of both hands, and the difficult MOD analysis formula is given. I hope that MODAPTS can be widely applied to China's industrial engineering in the application of big data and Internet of Things human factors engineering and the promotion of Made in China 2025.

Keywords: Big data; Human factor engineering; MOD time value; Time limit action.

1. Overview of MODAPTS

It is more efficient if we calculate the working process in seconds in industrial production. If all the work in our factory is scheduled in 0.1 seconds, is it more efficient? This paper introduces this technology [1]. Scheduled Time Standard Method (PTS) is an internationally recognized advanced technology for setting time standards. Scheduled time standard is a kind of job measurement technology, by which the working time reaching a certain level of efficiency can be specified according to the time of people's basic actions (classified according to the nature of actions and the working conditions when performing actions). MODAPTS (Modular Arrangement of Determined Time Standards) was put forward by G. C. Heyde of AUSTRALIA in 1966. He combined the use of various action analysis techniques with ergonomics, and explored and established MODAPTS techniques. MODAPTS are easy to understand, easy to learn and easy to remember [2]. There are 21 basic actions (and additional factors), and action symbols are integrated with time values; The MOD value can be adjusted, see Figure 1.
2. The basic time, system and verb notation of MOD

Definition of MOD time value

1) The movement of fingers is regarded as a unit, and other movements are expressed as integral multiples of finger movements.

2) Classify the used body parts with 21 marks.

3) The unit of time is expressed in MOD. *1 MOD = 0.129 seconds = 0.00215 minutes (at economic speed)

The mark of MOD method is consistent with the time value, so it is easy to use.

Basic system and motile notation [3]. The time value of MODAPTS shows the difference of action time according to the body parts. It is divided into moving action, ending action and combining action (etc.), which is composed of 21 actions and 8-time values, see Table 1.
### Table 1 MODAPTS verb symbol

| Classification | Content | Symbol | Additional condition |
|----------------|---------|--------|----------------------|
| Moving action  | Mobile  | Finger movement | M1                   |
|                |         | Wrist movements  | M2                   |
|                |         | Arm movement     | M3                   |
|                |         | Big arm movement | M4                   |
|                |         | The act of stretching one’s arms | M5 |
| Type movement  | Continuous and repeated reflection actions | M1/M2 |
| Ending action  | Grasping | Touch, contact | G0                   |
|                |         | Grabbing without attention | G1   |
|                |         | Complex grasping | G3 | Need spiritual attention |
|                | Place   | Simple placement (do not look at it visually) | P0 |
|                |         | More complex placement such as alignment (visual inspection is necessary) | P2 | Need spiritual attention |
|                |         | Placement with assembly purpose (asymmetric) | P5 | Need spiritual attention |
| Lower limb movements | Footsteps | Pedal action | F3 |
|                | Thigh movement | Walking action | W5 |
| Other actions  | Independent action (other actions stop while this action is in progress) | Visually observe (find out) | E2 |
|                |         | Correction (re-grasping) | R2 |
|                |         | Judgment and reaction (consideration) | D3 |
|                |         | To press (press) | A4 |
|                |         | Rotating action | C4 |
|                |         | Bend over-stand | B17 | Reciprocating |
|                |         | Sit down-Get up | S30 | Reciprocating |
| Additional factors | Limb movements that can be performed at the same time | Rotating action | C4 |
|                |         | Weight factor (load-bearing action) | L1 |

Note: MODAPTS method, 1MOD = 0.129S = 0.13S at ordinary speed, 1MOD = 0.1S at skilled labor speed, and increases by 10% 1 mod = 0.14 s after considering fatigue factors; The greater the action amplitude, the greater the time modulus.

### 3. MOD action definition and analysis

3.1. *Moving actions M1, M2, M3, M4, M5*

1) Finger movement M1: indicates the movement performed with the part before the third joint of the finger, with a time value of 1MOD and a moving distance of 2.5cm.

2) Wrist movement M2: one-time movement with the front part of wrist joint, the time value is 2MOD, and the movement distance is 5cm. Depending on wrist movements, you can not only do lateral movements, but also do up and down, left and right, oblique and arc-shaped movements [4].

3) The movement of forearm M3: the movement of forearm (including hands and fingers) before elbow with elbow joint as fulcrum. Every action is set as M3, the time value is 3MOD, and the moving distance is 15cm. Because of the direction of hand and forearm movement, the elbow joint must move back and forth [5]. The back-and-forth movement of elbow joint is regarded as the auxiliary action of active M3. Within the moving range of M3, the possible operation area is called normal operation range.
4) The action M4 of the big arm: with the movement of the elbow, the small arm and the big arm extend out in the natural state. Its time value is 4MOD, and its moving distance is generally 30cm. When the arm is fully extended, the auxiliary action of leaning forward is still M4 in terms of time value.

5) The action M5 of straightening the big arm as far as possible: the action of straightening the arm as far as possible because of natural straightening of the arm. In addition, the movement of extending the whole arm from the front of one's own body to the opposite side is also indicated by M5. Its time value is 5MOD and its moving distance is generally 45cm. Continuous M5 movements should be minimized. There are also special movement actions (reflection actions).

3.2. End action G0; G1; G3; P0; P2; P5

1) Touching G0: the action of touching an object with fingers or hands. This action has no intention of catching the target, just touching it. It is an instantaneous action, so there is no action time.

2) Grasp G1 simply: simply grasp the ground with fingers and hands. The time value is 1MOD. There is no hesitation in grabbing objects with hands or fingers under natural relaxation conditions, and there are no obstacles near the grabbed objects.

3) Complex capture G3: if attention is needed and G1 cannot be used, the time value is 3MOD; There is hesitation when grasping the target object, or there are obstacles around the target object; Or the destination is relatively small, and it is not easy to catch it; Or the object is easily deformed and fragile; Just a simple finger closure can't catch it.

4) Simple placement P0: after transporting the grabbed item to the destination, directly put it down. There is no need to look at the surrounding situation with eyes; There is no special requirement for placement.

5) Pay attention to placement P2: the action of putting things to the destination, and the action of making a correction by staring at them with eyes. Its time value is 2MOD. P2 action is suitable for situations where the object position or designated position can be roughly determined, but the fit tolerance is poor.

6) Placement P5 requiring attention: correctly place the object at the specified position or cooperate; It is more complex than P2, and often needs to be accompanied by more than two corrective actions [6]. You need to observe with your eyes from beginning to end; Hesitation in action; Combination of moving action and ending action. No matter what action, after moving action, it must be accompanied by ending action.

4. Simultaneous action analysis

Use different parts of the body to perform the same or different movements at the same time; When both hands can act at the same time, the action with large time value is called time limit action; The time value of time-limited action should be used to represent the time value of simultaneous action of both hands. For example, with an eraser and a sharpened pencil on the table, stretch out your hands at the same time (M3), grasp the rubber (G1) with your left hand and the pen (G1) with your right hand, and then put them in front of you.

4.1. Conditions for simultaneous action

Both hands do not act at the same time under any circumstances, but can act at the same time under the following two conditions. The final actions of both hands do not need attention, and can act at the same time; When only one hand chooses attention, it can also move at the same time.

1) When the final action of both hands does not require attention

For example, one hand grabs the screwdriver and the other hand takes the screw. Because both hands end in G1, they don't need much attention, so they can act at the same time.

2) When the ending action of one hand needs attention and the ending action of the other hand needs no attention. For example, one hand grabs the screw, and the other grabs a flat washer placed on the table. At this time, only one hand needs attention, so it can move at the same time.
Actions that require attention from both hands cannot be performed at the same time. Because currently, both hands need attention to finish their movements. For example, if two hands are used to pick up the flat gasket placed on the countertop at the same time, it is impossible to do it at the same time, but only finish the final action of one hand and then do it with the other hand.

4.2. Time limit action and its time value

When two hands can act at the same time, the action with the greatest time is called time-limited action, and the action with the smallest time is called being used by time-limited action. The time of simultaneous action of both hands is expressed by the time value of time-limited action. See Table 2 and Table 3 for the analysis examples of the time value of simultaneous action of both hands.

Table 2 End action two-handed action analysis

| Situation | Simultaneous motion | The ending action of one hand | The ending action of the other hand |
|-----------|----------------------|-----------------------------|----------------------------------|
| 1         | May                  | G0 or P0 or G1             | G0 or P0 or G1                   |
| 2         | May                  | G0 or P0 or G1             | P2 or G3 or P5                   |
| 3         | Impossible          | P2 or P3 or P5             | P2 or G3 or P5                   |

Table 3 Time limit action example

| NO | Left hand movement | Right hand movement          | Mark symbol | Frequency | MOD |
|----|--------------------|-------------------------------|-------------|-----------|-----|
| 1  | Grab parts A(M3G1) | Grasping and rotating toolM4G1 | M4G1        | 1         | 5   |

Because the ending actions of the left and right hands are G1, they do not need attention, so they can be carried out simultaneously.

The left-hand time value M3G1=4MOD, and the right-hand time value M4G1=5MOD. Therefore, the right-hand action is time-limited action. The small-time value of the left hand is called time-limited action, and the mark symbol of time-limited action is indicated by (), which does not affect the analysis result. When the time values of both hands are the same, the time value of one hand can be taken for calculation.

4.3. Difficulty------Analysis method when both hands need attention

Although it is impossible for both hands to pay attention, the method of moving and waiting can be used. For example, the left hand M3G3 and the right hand M4G3. Because the moving action does not require attention, both hands can be extended at the same time. When the left hand reaches the required position, it will grab G3. At this time, the right hand can't do G3 at the same time, so wait by the target. After the left hand finishes the action, the right hand only moves a little, and then it can finish G3. The reason why the right hand moves slightly is that it is impossible for people to pick things up with their stiff hands, and this action is M2. In this way, the left hand first finishes the action of M3G3, and then the right hand does the action of M2G3, and the time value is M3G3+M2G3=11MOD. If in the above example, the left and right hand movements are different successively, for example, the left hand moves first, and the situation is shown in Table 4.

Since the right hand extends out at the same time as the left hand, after waiting for the left hand to finish the M3G3 movement, the right hand moves the wrist again (M2) to do the grabbing movement, so the right hand movement is M2G3. It can be seen from Table 5 that right hand and left hand can extend at the same time. Right hand moves M4 first (at this time, left hand also extends M3 at the same time), then takes object G3, and then left hand makes a wrist M2 action to take object G3. Therefore, the time value is M4G3+M2G3=12MOD.
Table 4 Left hand first action

| NO | Left hand movement | Right hand movement | Mark symbol | Frequency | MOD |
|----|--------------------|---------------------|-------------|-----------|-----|
| 1  | Grab partsA M3G3   | Grab partsB M4G3    | M3G3M2G3    | 1         | 11  |

Table 5 Right hand first action

| NO | Left hand movement | Right hand movement | Mark symbol | Frequency | MOD |
|----|--------------------|---------------------|-------------|-----------|-----|
| 1  | Reach for parts A M3G3 | Reach for parts B M4G3 | M4G3 M2G3   | 1         | 12  |

From the above examples, even if the action is the same, the time value when the ending action needs attention (left hand and right hand do it first) is different. Analyze the main points when both hands need attention:

Firstly, analyze whether two hands can move at the same time. Secondly, if both hands need attention, see which hand is done first and which hand is done later. After waiting for the first hand to finish, the latter hand makes a move and waits for M2, and then makes the final action.

5. Lower limb and waist and auxiliary movements (brief description) F3, W5, B17, S30

1) Pedal action F3, step the heel on the board and do the foot neck action; The time value is 3MOD.
2) Walking action W5 the action of walking to move the body; Turning your body and moving your feet at the same time is also judged as walking; Each step of walking is represented by W5, and the time value is 5 mod. Walking to the last step, the action of hand and arm moving with it is m2; This is because in the last step, the hand is close to the target.
3) Bend over B17, the whole process from standing to bending, squatting, touching the ground on one knee, and then returning to the original state.
4) Sit down and stand up S30, sit in a chair and stand up again; The action time of pushing the chair backward with both hands when standing up and pulling the chair forward when sitting down is also included.

Auxiliary actions (outline) L1, E2, R2, D3, A4, C4
The weight factor L1 of the conveying action, the eye action E2, the corrective action R2, the judging action D3, the pressurizing action A4, and the rotating action C4.

6. Optimization and application cases of MODAPTS

In the application of MOD method in industrial engineering, we should replace and merge the moving action M, reduce the times of moving action M, replace and merge the grasping action G, simplify the grasping action, simplify the placing action P, and try not to use eye action E2 and correction action R2 as much as possible. Try not to do judgment action D3; Minimize the pedal movement F3; Try to reduce pressing and pressing A4, walking W5, body bending B17, body standing S30 and so on. The design connects workers’ work before and after.

Application case: Table 6 shows the left and right hand movement analysis of an operator assembling washers and bolts. During operation, both hands independently assemble the same products, and both hands move at the same time. Please make the following analysis. Fill in the table with comprehensive analysis expressions and model values. Calculate the normal time. If the discharge rate is 18%, calculate the standard time. We can get Table 7, Normal time = (20+26+12+3) × 0.129 = 61 × 0.129 = 7.869 s. Standard time =7.869 × (1+18%) ≈ 9.29s
Table 6 left and right hand movement analysis of an operator assembling washers and bolts

| Action description                  | Left hand | Right hand | Comprehensive analysis | Model value |
|-------------------------------------|-----------|------------|------------------------|-------------|
| 1. pick and place the rubber gasket | M3G3M3P2  | M3G3M3P2   |                        |             |
| 2. Take and place the fixing washer | M3G3M3P5  | M3G3M3P5   |                        |             |
| 3. Take and place bolts             | M3G1M2P2  | M3G1M2P2   |                        |             |
| 4. Pick and place the assembly parts | M3P0      | M3P0       |                        |             |

Table 7 Application case of an operator assembling washers and bolts

| Action description                  | Left hand | Right hand | Comprehensive analysis | Model value |
|-------------------------------------|-----------|------------|------------------------|-------------|
| 1. pick and place the rubber gasket | M3G3M3P2  | M3G3M3P2   | M3G3M2G3M3P2M2P2      | 20          |
| 2. Take and place the fixing washer | M3G3M3P5  | M3G3M3P5   | M3G3M2G3M3P5M2P5      | 26          |
| 3. Take and place bolts             | M3G1M2P2  | M3G1M2P2   | M3G1M2P2M2P2          | 12          |
| 4. Pick and place the assembly parts | M3P0      | M3P0       | M3P0                   | 3           |

7. Conclusions
When using MOD to determine the operation time, if there is action, we can determine the operation time. By summarizing these time values, we can find the standard time value. The working efficiency is improved to 0.1 second. It can be applied in big data, Internet of Things, human factors engineering, promoting Made in China 2025, and industrial engineering 6sigma control.

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