Balance Optimization of Sports Shoe Production Line Based on ISM-MICMAC

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Abstract. An in-depth analysis of the influencing factors and their mechanisms of action on the balance of production lines in A sneaker factory was conducted using explanatory structural modeling (ISM) and cross-influence matrix classification (MICMAC). The ISM model clearly points out the employee's work attitude (P1) as the core driver and reveals its hierarchical relationship: the bottom driver (P1) directly or indirectly affects the middle linkage factors (P2, R1, R2, Z1), and ultimately acts on the dependency factors (Z2). Then, combined with MICMAC analysis to quantify the drivers and dependencies of each factor, the factors were classified as independent (P1), linked (P2, R1, R2, Z1) and dependent (Z2), and the optimization priority was clarified. A four-part optimization strategy of "Motivation-Prevention-Agility-Collaboration" was proposed, including employee incentives, preventive maintenance of equipment, enhanced supply chain resilience, and digital field management, which effectively solved productivity problems and improved resource utilization.

Keywords: ISM, MICMAC, factory production line, optimization.

1 Introduction

With the changes in the economy in recent years, the competition in the global manufacturing industry has been intensifying. The optimization of the factory production line is the core support for enterprises to dominate in the competition, and it is the core problem to be solved as a priority for manufacturing enterprises. For most of the factory manufacturing is nothing more than a precise manufacturing process, the demand for changing orders and traditional materials, personnel, equipment and other factors to affect the production efficiency of the production line, resulting in a waste of resources, the production line is not balanced as well as the product qualification rate is not stable and other issues. In actual production, enterprises usually use algorithmic models, value stream analysis and other methods to seek solutions to eliminate obvious problems in the production process by statistically controlling various parameters in the production process, and mainly focus on the optimization of a single local link. However, these traditional methods ignore the hidden factors (e.g., organizational behavior) and the influence of the relationship between multiple factors.

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Therefore, in order to solve these neglected hidden factors (e.g., organizational behavior) and the influence relationship between multiple factors, Interpretive Structural Modeling (ISM) with Cross-Influence Matrix Classification (MICMAC) is introduced here, and the ISM-MICMAC method is used to construct the hierarchical relationship between the influencing factors in the case of A Shoe Factory, which systematically reveals the interaction relationship between the influencing factors and solves the optimization problems that are difficult to be solved by traditional optimization methods.

2 Conceptual Introduction: Interpretive Structural Modeling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC)

Interpretive Structural Modeling (ISM) is a system analysis methodology used to reveal the hierarchical relationships and interactions between elements in complex systems. [1-2] The core of this method is to construct the adjacency matrix by using the interrelationships of the influencing factors of disorder, and to obtain the hierarchical model of the influencing factors of disorder by calculating the reachability matrix of this matrix, which intuitively shows the hierarchical relationship between the influencing factors and clarifies the hierarchical framework of the influencing factors of disorder for the decision makers, which is conducive to the subsequent optimization strategy development and implementation of targeted. The advantage of ISM method is that using this method can visualize the abstract disordered interactions, which has significant advantages for production line optimization in multi-factor coupled industrial scenarios, and can help enterprises to quickly identify the core elements, and then formulate reasonable optimization strategies.

The method of cross-influence matrix multiplication (MICMAC) is a system interaction analysis method based on matrix operations for quantifying the drivers and dependencies of factors in a system. [3-4] This method uses a cross-influence matrix to express the strength of the interaction between the influencing factors, identify the direct or indirect links between the factors, and classify the influencing factors as dependent, independent, linked, etc., in order to identify the key optimization nodes. It is widely used in strategic planning, resource allocation, etc., and is suitable for optimization scenarios that require a balance between stability and efficiency.

3 Production Line Balance Optimization Analysis Based on ISM-MICMAC

3.1 Establishing the ISM Model.

When using ISM and MICMAC methods to optimize the production line of A shoe factory, the first step is to establish an ISM model. Here, the ISM model is built as an example for A sports shoes factory:

Identifying Influencing Factors.

A sports shoes factory is a medium-sized sports shoes production factory, which mainly produces sports shoes and other footwear products. Through field research and questionnaire survey of the factory personnel, it was found that there is a production line imbalance problem in A sports shoes factory, and its influencing factors were determined through further research and review of related production line balance papers [5-8]:

Personnel factors:

P1: Negative work attitudes of workers: workers lack work enthusiasm or motivation, resulting in low productivity.

P2: Inadequate worker skills: workers lack the necessary operating skills or experience, resulting in low productivity.

Production Factors:

R1: High equipment failure rate: equipment aging or improper maintenance, resulting in increased downtime, affecting the production rhythm.

R2: untimely supply of materials: untimely supply of raw materials or parts, resulting in production line downtime.

Management factors:

Z1: Irrational production plan: the production plan is not formulated scientifically, resulting in mismatch of production capacity of each process and bottlenecks.

Z2: Chaotic on-site management: the lack of effective organization and coordination of on-site management leads to low efficiency.

After discussions with four domain experts, the mutual influences among these six factors were determined, and the following adjacency matrix was established: As shown in Table 1.

Table 1. Adjacency Matrix

	P1	**P2**	**R1**	**R2**	**Z1**	**Z2**
P1	0	1	1	0	0	0
P2	0	0	1	0	0	0
R1	0	0	0	1	0	0
R2	0	0	0	0	1	0
Z1	0	0	0	0	0	1
Z2	0	0	0	0	0	0

Note: A "1" in the matrix indicates that the row factor has a direct effect on the column factor, while a "0" indicates that there is no direct effect.

This adjacency matrix is then computed by Boolean algorithm to obtain its reachability matrix as follows: As shown in Table 2.

Table 2. Reachability Matrix

	P1	**P2**	**R1**	**R2**	**Z1**	**Z2**
P1	1	1	1	1	1	1
P2	0	1	1	1	1	1
R1	0	0	1	1	1	1

R2	0	0	0	1	1	1
Z1	0	0	0	0	1	1
Z2	0	0	0	0	0	1

ISM Model Structure

The ISM Model Structure is constructed based on Table 1 and Table 2 as follows:

Hierarchy Construction: Based on the data in the relationship matrix, determine the hierarchy of influencing factors.

First Layer: P1, P2, R1. Basis: Their reachable set includes themselves and higher-level factors, but they are not directly influenced by other factors.

Second Layer: Z1, R2. Basis: Driven indirectly by the underlying factors and affects the top layer.

Third Layer: Z2. Basis: Indirectly influenced by all lower factors, but does not drive any other factors itself.

ISM Model Hierarchical Diagram:

Bottom Layer:

P1 (attitude) → P2 (Insufficient skills) → R1 (Equipment malfunction)

↓

Middle Layer: R2 (Material supply) → Z1 (Unreasonable schedule)

↓

Top Layer: Z2 (Site management chaos)

3.2 MICMAC Method Application

Then, based on the established ISM model, the following table was created and MICMAC analysis was performed based on the driving force (number of direct influences) and dependence (number of directly influenced) of each influencing factor. As shown in Table 3.

Table 3. Calculation of Driving Force and Dependence

Factor	Driving Power	Dependency
P1	2	0
P2	1	1
R1	1	2
R2	1	1
Z1	1	1
Z2	0	1

According to Table 3.The MICMAC classification, using the median of driving force and dependence as thresholds (driving force median = 1, dependence median = 1), divides factors into four categories:

Independent Factors (Quadrant I): High driving force, low dependence P1 (Driving force = 2, Dependence = 0).

Interlinked Factors (Quadrant II): High driving force, high dependence P2, R1, R2, Z1 (Driving force = 1, Dependence ≥ 1).

Dependent Factors (Quadrant III): Low driving force, high dependence Z2 (Driving force = 0, Dependence = 1).

Autonomous Factors (Quadrant IV): Low driving force, low dependence None.

MICMAC analysis results:

Independent: P1 (Poor attitude). Strategies: Prioritize incentive mechanisms and motivation programs.

Linkage: P2, R1, R2, Z1. Strategies: Systematically improve skills, maintenance, supply chain, and production plans.

Dependent: Z2 (Chaotic management). Strategies: Address through optimization of linkage factors.

4 Recommendations and Conclusions

4.1 Optimization Recommendations

The ISM-MICMAC analysis concludes that work attitude is the core driver that needs to be addressed as a priority, while chaotic site management is the ultimate manifestation of systemic deficiencies that need to be addressed by optimizing the associated factors. Factors such as production planning and material supply are intermediate links that need to be better managed.

Prioritize improving worker motivation and worker skills. Improvement of the worker incentive system to increase the benefits of efficient work for workers, which in turn increases their motivation to work. The introduction of VR technology allows workers to perform virtual drills to improve skill proficiency.

Establishment of a robust preventive production program. From the analysis, it can be seen that equipment failure will have a strong correlation effect on the production schedule, so in addition to taking regular equipment maintenance and repair, but also to prepare a backup production plan to protect the production efficiency.

Create a resilient supply chain. In the face of insufficient supply of materials. There is a need to establish a public joint inventory mechanism with suppliers and visualize the tracking of purchase orders using blockchain technology. On the logistics end, we lay out regional collection centers, optimize distribution paths with Internet of Things devices, build double insurance for buffer stocks and safety cycles, enhance supply chain flexibility, and form a risk-resistant supply chain network.

Establishment of digital site management. In order to solve the confusion of the management site, a digital management platform should be established. Establishment of abnormal alarm system, production line problems can be quickly reacted to solve the problem. Establish standardized guidelines for management to identify and prevent management problems in advance.

4.2 Conclusion

Through the implementation of the above optimization recommendations, the production line of Factory A has been significantly optimized, as evidenced by a 15.4% year-on-year decrease in energy consumption (kWh) per unit of Factory A from 42.7 to

36.1 before the implementation, a 15.4% year-on-year decrease in daily production (pairs) from 8,200 before the implementation to 9,750 after the implementation, and a decrease in defective product rate from 3.2% to 1.8%. It can be seen that the use of ISM-MICMAC method can quickly locate the core influencing factors of production line balance in A shoe factory, and then quickly formulate corresponding strategies to solve the optimization problem.

References

1. Wang Jingmin, Kang Junjie. Analysis of Energy Demand Influencing Factors Based on Interpretive Structural Model [J]. China Electric Power, 2017, 50(09): 31-36.
2. Cheng Hao, Mao Xue, Li Jiming. Research on the Promotion Factors of the Resilience of Prefabricated Building Supply Chains Based on ISM-MICMAC [J]. Journal of Harbin University of Commerce (Natural Science Edition), 2024, 40(06): 738-745.
3. Chen Yuting, Jiang Chunyan, Song Chengwen. Research on the Influencing Factors of Enterprise Digitalization Capability — ISM-MICMAC Analysis Based on the TOE Framework [J/OL]. Science and Technology Progress and Countermeasures, 1-10 [2025-02-14].
4. Liu X, Lei T, Boré A, et al. Identification of Drivers of Global Trade in Plastic Waste Based on GCA and ISM-MICMAC Model: Case Studies of China, USA, and South Africa [J]. Journal of Environmental Management, 2025, 375124235-124235.
5. Beldar P, Fathi M, Nourmohammadi A, et al. Transfer Line Balancing Problem: A Comprehensive Review, Classification, and Research Avenues [J]. Computers & Industrial Engineering, 2025, 201110913-110913.
6. Huang Huaxing, Wei Haiyan, Li Minqian, et al. Application of Industrial Engineering in Production Line Planning [J]. Equipment Manufacturing Technology, 2024, (07): 106-109.
7. Kubilay B, Öztop H, Çil AZ. Constraint Programming Models for Parallel Robotic Assembly Line Balancing Problems Considering Energy Efficiency [J]. Flexible Services and Manufacturing Journal, 2024, (Prepublish): 1-42.
8. Schäfer L, Tse S, May CM, et al. Assisted Production System Planning by Means of Complex Robotic Assembly Line Balancing [J]. Journal of Manufacturing Systems, 2025, 78109-123.