1. **Introduction**

Expressway is an important indicator to measure the level of economic development and modernization of a country or region. As early as the 1920s and 1930s, developed countries in the western world, such as Germany, Italy, and the United States, showed an upsurge of highway development and construction aided by advanced management techniques, including flexible management.

2. **Flexible Management**

2.1. **Flexible management**

Flexible management emerged in the western countries in the late 1980s. At that time, economic saturation and excessive oversupply posed severe challenges to enterprises in the western world. In Japan, Toyota, an automobile manufacturing giant, took the lead in proposing the concept of flexible management. Its FMS flexible manufacturing system changed Toyota's traditional production technology in the past century, drawing attention from the academic world and the industry. For this reason, Mandalbaum, president of Toyota, specifically defined flexibility as "the ability of the manufacturing system to cope with changing environment or instability brought by the environment". Literally, it refers to adaptability, flexibility, and universal application. In China, flexible management is a kind of flexible human-oriented management, which not only exists at the philosophical level, but also has been fully applied in management practices, featuring an integration of theoretical and practical experiences. In conclusion, flexible management is dynamic, flexible, active, systematic and efficient. It is necessary to adopt flexible management in enterprises and related production projects as it emphasizes emotional factors involved in management and the pursuit of organizational flexibility, thus ensuring the concentration and distribution of power among various levels of the organization. On the basis of flexible decision-making mechanism, it pursues flexible management of services,
marketing, production and even mentality. At present, flexible management has made great progress in the management of production, information and human resources.\[^{[1]}\]

Despite the current trend of information age, flexible management has been fully integrated into information management. For example, many enterprises have established information system architecture (ISA), the foundation of flexible management for enterprise information system. It aims at optimizing the flexible management of enterprise ISA from the overall level to establish a socialized and technical integration system, and divide social subsystem and technical subsystem for enterprise ISA, thus proposing the concept of flexible management. The flexible supply chain based on flexible management system incorporates information system and transportation system in combination with the demand of customers of node enterprises as the basic traction, and utilizes the division of system functions, cooperation and coordination to support supply chain management.

2.2. Flexible schedule-based expressway construction projects

To avoid uncertainties and conflicts of resources, it is necessary to analyze the flexible schedule management to ensure that all factors involved in flexible schedule management are taken into account. For example, flexible management and constraint management can be used to jointly guide the construction of expressway projects, with the constraints serving as the basis of overall adjustment so as to improve the flexibility of project schedule. Specifically, the flexible schedule management of expressway construction projects consists of four steps to regulate and control the project as a whole, and systematically transform flexible management into continuous improvement.

Secondly, it is necessary to find out constraints in the system and decide how to transform constraints into contributing factors in the management system.

Thirdly, ensure consistency between other tasks in the system and potential- tapping decisions made in the previous step.

Fourthly, go back to the first step to ensure that flexible management will not restrict the progress of expressway construction projects.

3. Flexible Schedule Management in Expressway Construction Project

There are various influencing factors in expressway construction projects, which take place in different stages of construction, and could lead to management deviation in expressway construction projects. The following briefly analyzes some methods applicable in flexible schedule management of expressway construction projects.

3.1. PDCA flexible schedule management

PDCA (Planning, Design, Check, Act) flexible schedule management develops the management process based on the production links. In short, it is a process of managing large loops and small loops, with each loop constantly moving forward in an orchestrated manner. PDCA can analyze specific target in the management to ensure that management activities run in a circular state and constitute a comprehensive circular structure. In the process of circulating operation, the schedule management will be effectively improved, as shown in Figure 1.

![Figure 1 PDCA Management](image-url)
The management of expressway construction project needs to ensure flexible control of PDCA, thus improving operation efficiency and ensuring both quality and progress of schedule. A large amount of data and information need to be collected through pareto diagram, control chart, etc. to ensure flexible and effective progress control.

3.2. Schedule tracking of flexible schedule management
Schedule tracking, also called "banana" curve, is a common approach used in the flexible schedule management of expressway construction projects. Among activities in the network, all activities except key activities are marked by the earliest and latest start time as TES and TLS respectively. The two indicators could be the same in certain time periods, which could be drawn by the progress curve S. In the construction of expressway, it is necessary to draw the actual progress curve-R curve by utilizing the "banana" curve. The banana curve is compared with the R curve to make sure that the R curve stays within the range of the banana curve, thus optimizing schedule control and ensuring that both curves are in an ideal state. If the R curve is above the TES curve, it means that the actual progress is ahead, and if the R curve is below the TES curve, it means that the actual progress is delayed. The abscissa of the banana curve's end point and the predicted R curve's end point indicates the deviation value, which can be combined with the actual progress to analyze the construction progress of the expressway project. The indicator of $\Delta T$ could be used as the deviation index of the construction progress for dynamic analysis.

To sum up, the application of PDCA and banana curve in expressway schedule control can help develop a rolling flexible schedule control system, which will be studied and analyzed in case studies. For example, a variety of corresponding early warnings could be proposed based on the expressway construction project along with flexible adjustment of the progress. Aided by relevant analysis tools, a set of progress management procedures and prevention plans will be introduced and illustrated in real scenarios.[5]

4. Case Study of Flexible Schedule Management of Expressway Construction Project

4.1. Overview
A national key highway, which served as an important channel to connect two cities. To construct a national network of key expressways aiming at "shortening distance between cities to eight hours", engineers adopted flexible schedule management for this purpose. The expressway in the case study was 3km in length, including subgrade earthwork, bridge engineering, tunnel engineering and so on. Among them, the bridge adopted prestressed concrete T-beam, and the shaft was 8m in net diameter and 180m in depth.

4.2. Case study: Application of flexible management

4.2.1. Generate engineering construction process
In an expressway construction project, flexible critical chain and flexible interval were mainly used to jointly build a mechanism of flexible schedule management. In this process, there were 30 days for construction preparation that started from subgrade engineering construction, including tunnel opening construction, bridge pile foundation construction, shaft excavation, opening excavation and slope support, opening masonry, opening excavation and primary support, opening secondary lining, girder erection and bridge deck pavement, pier and abutment body, T-beam prefabrication, pavement decoration engineering, lining and finishing supporting construction.

4.2.2. Generate plans for flexible schedule management
Generating plans for flexible schedule management is a key step in a project. First of all, it is necessary to determine what's involved in the flexible schedule management and synchronously arrange the network tasks. In case of conflicts, it is necessary to rearrange tasks, solve resource
conflicts and identify the longest chain as the basis of flexible schedule management plan. For example, resource conflict was eliminated at the project closing along with adjustment of resource management based on lining, thus ensuring the progress of the project.

Finally, in the process of evaluation and summary, it is necessary to dig deep into flexible schedule management to re-examine the schedule and check the project cycle. For flexible management, resource conflict is a problem that requires prompt solution to ensure a decent system of resource control and management and the establishment of a flexible engineering management system.[3]

4.2.3. Procedures of flexible schedule management
Firstly, solve resource conflict based on flexible schedule management.

Secondly, illustrate the items involved in expressway construction projects using visuals and invest more resources to ease resource conflicts, thus shortening project cycle. For example, increasing investment in construction facilities and pile foundation construction have proved effective in shortening project cycle.

Finally, return to the initial stage to identify the schedule management, and avoid being trapped by thinking inertia which could restrict the construction of expressway projects.

4.2.4. Quantitative analysis of flexible control of engineering project schedule
Combined with flexible schedule management, this paper makes quantitative analysis to investigate unforeseen factors in the process of expressway construction project in an effort to help avoid construction deviation from the original plan. In other words, it is necessary to adjust the plan to ensure the three major factors of quality, progress and cost. For schedule adjustment, it is necessary to analyze the three quantitative indicators at a certain moment and make clear uncertainties in the construction of the project, thus ensuring that progress of the project based on the primary goals and quantitative optimization of the flexible management. Here, it is necessary to apply quantitative optimization to regulate the process of project construction.

For example, by analyzing a total of X comprehensive control schemes in the construction progress of a project, we could define a total of y target attributes, including the progress guarantee attribute. Set y=6(6 target attributes), and the attribute matrix M is formed by combining the attribute values of each scheme. The matrix M should be as follows:

\[
M = (m_{ij})_{3x6} \quad (i = 1,2,\ldots,y; \quad j = 1,2,\ldots,x)
\]

Establish matrix M combining standardized attribute matrix M and determine standardized elements M. However, considering uncertainties in the expressway construction projects, it is necessary to analyze the relatively important attributes based on the target. Considering all the uncertainties in the project, it is necessary to analyze the conditional entropy value as follows:

\[
e(m_i) = \sum_{j=1}^{k} \frac{m_{ij}}{m_j} \ln \frac{m_{ij}}{m_j} / \ln(x)
\]

Based on the basic properties of entropy, the smaller the \(e(m_i)\) is, the more important it is for the target attribute. It is necessary to evaluate the target and verify its importance via positive correlation reaction. It is possible to analyze the 1-e(mi) reaction based on standardized importance weight, which is an indicator of the target attribute. The larger the \(e(m_i)\), the greater its weight, which means that there are obvious differences between values in the target attribute of i, a phenomenon that requires prompt identification, investigation and greater attention[4].
4.3. Analysis of flexible management through case study

Uncertainties during the construction of an expressway project require readjustment and progress planning without increasing investment so as to control the project cycle. In this paper, flexible schedule management was adopted to find out restrictive factors affecting the project schedule based on specific project conditions while avoiding resource conflicts to maximize the efficiency of the project. Meanwhile, risk integration was also considered in combination with uncertainties to adjust the flexible management buffer zone and eliminate uncertain risk factors existing in engineering design and construction, thus enhancing the flexibility of project schedule, ensuring progress, and finally limiting the project cycle within a reasonable range (700 days).

Generally, flexible project management has proved more prominent in rigid performance while less flexible compared with the latter as evidenced by its failure to identify restrictive factors that determine the project cycle or adjust the construction efficiency. On the whole, it is relatively inactive in controlling the project cycle, which is a typical static management. However, flexible schedule management works better in the identification of items involved in the determination of project cycle and elimination of uncertainties while solving resource conflicts and unclear management divisions, bringing positive influences to the expressway construction project. In this process, it effectively ensures the realization of project goals. In terms of management functions, it is necessary to highlight the flexibility, dynamics, initiative, efficiency and systematism of management.

For example, in the construction stage, it is necessary to clarify the aims of project management for progress adjustment. Based on opinions from experts, the analysis scheme is determined. Meanwhile, the progress assurance, quality assurance, cost assurance, technical assurance and safety assurance of different schemes vary from each other. Based on the above five items, a standardized matrix M is calculated, as shown in Figure 2.

\[
M = \begin{bmatrix}
\frac{2}{3} & 0 & 1 & 1 \\
1 & \frac{1}{2} & 1 & 0 \\
1 & \frac{1}{2} & 0 & 1/2 \\
1 & \frac{1}{3} & \frac{1}{3} & 0 \\
1 & 0 & \frac{1}{2} & 0 \\
1 & \frac{1}{2} & 0 & \frac{1}{2}
\end{bmatrix}
\]

Figure 2 Standardized Matrix M

Based on standardized matrix M, the progress assurance was analyzed and the weight value was calculated at 0.1288. A weighted and standardized matrix is thus established, where the ideal point and anti-ideal point of the matrix are defined and the distance d of the ideal point A is calculated to identify the distance, proximity and priority.

Generally, by analyzing data acquired from certain section of an expressway based on flexible schedule management, we established constraint conditions for data analysis and investigated approaches to optimize flexible management based on empirical studies, thus improving flexibility of traditional rigid management and avoiding passive control. In other words, it is necessary to focus on uncertainties brought by the environment and analyze possible risks in the construction based on flexible schedule management. It is necessary to focus on the overall situation so as to better adapt to changes, play the initiative for flexible management and guarantee of investment, quality and progress of expressway project construction, thus highlighting the technical advantages of flexible management.\[5\]
5. Conclusion:
The construction of expressway project needs to be integrated with advanced technologies and flexible management, which should be applied to establish the flexible management-based supply chain, marketing and human resources mechanism to optimize the overall progress of expressway construction. By building up the core theories, management techniques, innovative application and supporting environment of expressway construction projects, more valuable decision-making ideologies, analysis tools, items and thinking patterns will be integrated into the expressway construction project.

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