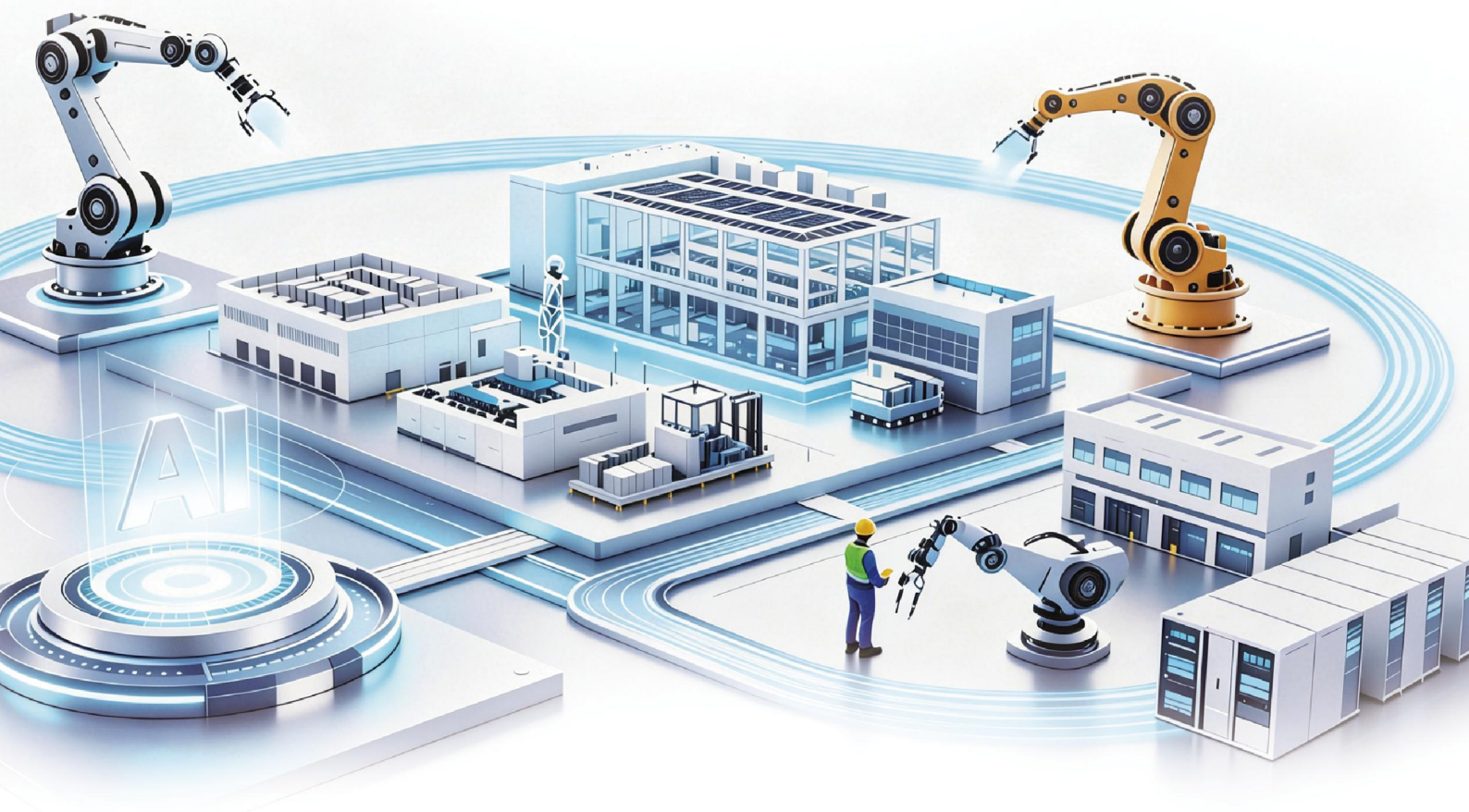


IMEC × 国家智能制造专家委员会

# 海外智能工厂案例集

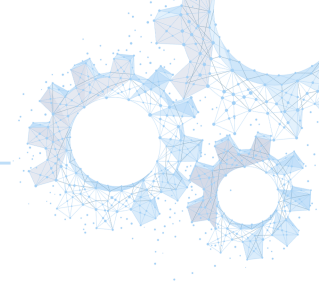
(2026版)



国家智能制造专家委员会行业应用工作委员会

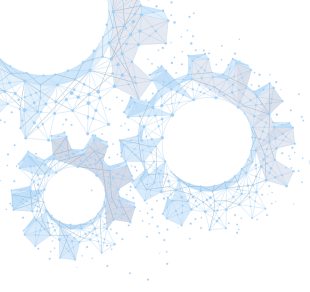
2026年5月





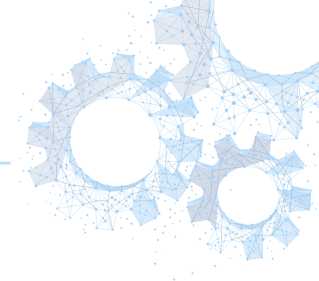
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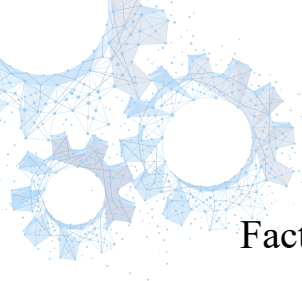
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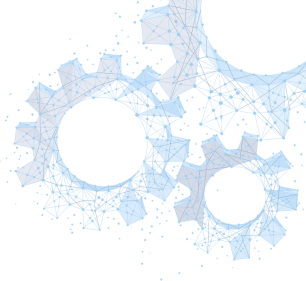
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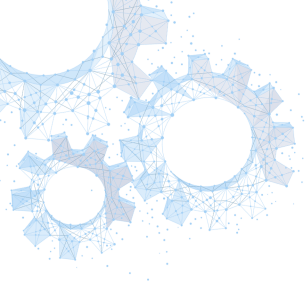
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## 前言

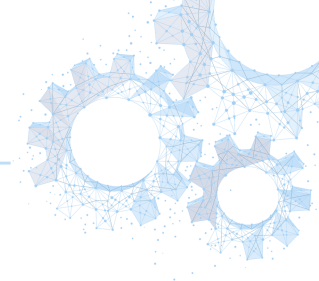
智能工厂作为新一代信息技术、先进制造技术和先进管理理念融合创新的重要载体，是实现智能制造的关键抓手，是制造业数智化转型的主阵地。为推动智能制造向更大范围、更高层次和更深程度拓展，2024年，工业和信息化部、国家发展改革委、财政部、国务院国资委、市场监管总局、国家数据局六部门联合启动智能工厂梯度培育行动，构建起“基础级—先进级—卓越级—领航级”四级培育体系。

领航级智能工厂作为这一体系的最高层级，被赋予探索未来制造模式、重塑制造系统架构、打造全球标杆样板的战略使命，是加快发展新一代智能制造的核心承载。首批15家领航级智能工厂是从全国8000余家先进级智能工厂、500余家卓越级智能工厂中优中选优产生，具有行业引领的制造模式、智能水平和价值效益，对我国制造业转型升级将起到明显的标杆示范效应。在制造模式探索方面，形成了数智精益、敏捷定制、共享制造、岛式制造等新兴制造模式，满足了高效率、高精度、高柔性和高质量的生产要求；在前沿技术实践方面，人工智能已渗透70%以上的业务场景，沉淀垂直领域模型超6000个，并加速向工艺优化、设备管理、人机协同等生产核心场景纵深渗透；在价值效益创造方面，领航工厂生产效率平均提升29%，产品不良率平均降低47%，关键绩效指标显著高于行业平均水平，并推动企业从“产品制造商”向“产品+服务+解决方案”综合提供商转型。



同时，我国智能工厂的价值，已不止于自身智能化升级，更在于它们已构建起多层次、开放式、协同化的全球智能制造生态，正在打破企业、产业、地域的限制，以产业链上下游协同为根基，以“母工厂”的形式将成熟的制造模式、先进的技术装备、完善的标准体系与高效的管理经验打包输出，将“中国方案”和“中国智慧”贡献给全球制造业。

为系统总结国内外智能工厂的建设经验与创新成果，在国家智能制造专家委员会的指导下，中国信息通信研究院联合相关企业共同编制《领航工厂案例集》，深入剖析 15 家领航工厂在制造模式变革、关键技术创新、产业链协同赋能等方面的典型实践，全景展现其作为核心技术策源地、新型装备试验场和标准规则输出中心的巨大价值，同时编制了《海外智能工厂案例集》，系统分析了 13 家海外智能工厂在制造能力推广、场景落地探索与属地合规运营等方面的典型实践，希望与全球制造企业共享我国智能工厂在海内外的建设成果，为广大制造企业数智化转型提供可借鉴、可落地的有益指南。

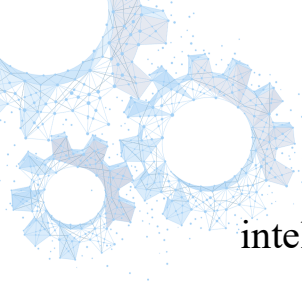


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## Foreword

As an important carrier for the integration and innovation of New Generation Information Technology, Advanced Manufacturing Technology and advanced management concept, intelligent factory is the key to realize intelligent manufacturing and the main position of digital and intelligent transformation of manufacturing industry. In order to promote the development of intelligent manufacturing to a wider range, a higher level and a deeper level, in 2024, the six departments of the Ministry of Industry and Information Technology of the People's Republic of China, the National Development and Reform Commission, the Ministry of Finance, the state-owned assets supervision and Administration Commission of the State Council, the State Administration of Market Supervision and administration, and the National Data Bureau jointly launched a smart factory gradient cultivation campaign, a four-level cultivation system of “Basic level-advanced level-excellent level-pilot level” has been established.

As the highest level of this system, the pilot-level intelligent factory is endowed with the strategic mission of exploring the future manufacturing mode, reshaping the manufacturing system architecture, and creating a global benchmark model, it is the core carrier of accelerating the development of a new generation of



intelligent manufacturing. The first 15 pilot-level intelligent factories are selected from more than 8000 advanced intelligent factories and more than 500 excellent intelligent factories across the country, with industry-leading manufacturing models, intelligence levels and value benefits, it will play a significant benchmarking effect on the transformation and upgrading of our manufacturing industry. In the exploration of manufacturing mode, it has formed new manufacturing modes such as smart lean, agile customization, shared manufacturing and island manufacturing, which meet the requirements of high efficiency, high precision, high flexibility and high quality. In terms of cutting-edge technology practice, artificial intelligence has penetrated more than 70% of business scenarios, precipitating more than 6000 vertical domain models, in terms of value creation, the production efficiency of the pilot plant is increased by an average of 29% , and the product defect rate is reduced by an average of 47% , the key performance indicator is significantly higher than the industry average, and promotes the transformation of enterprises from “Product manufacturer” to “Product + service + solution” integrated provider.

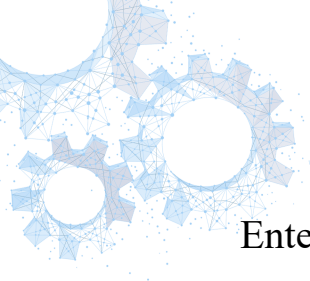
At the same time, the value of our country's intelligent factories has not only been their own intelligent upgrading, but also lies in the fact that they have built a multi-level, open and collaborative global intelligent manufacturing ecology, is breaking the restrictions of



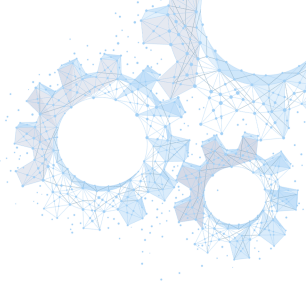
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enterprises, industries, and regions, based on the coordination of upstream and downstream of the industrial chain, the mature manufacturing mode, advanced technology and equipment, perfect standard system and efficient management experience are packaged and exported in the form of“Parent factory”, to contribute“Chinese solutions” and“Chinese wisdom” to the global manufacturing industry.

In order to systematically summarize the construction experience and innovation achievements of intelligent factories at home and abroad, under the guidance of the National Expert Committee on Intelligent Manufacturing, China Academy of Information and communications and related enterprises jointly compiled the pilot factory case collection, the typical practices of 15 pilot factories in manufacturing mode change, key technology innovation, and industrial chain collaborative empowerment are deeply analyzed, it shows its great value as a source of core technologies, a testing ground for new equipment, and a center for exporting standards and rules. At the same time, it compiled the overseas smart factory case collection, the typical practices of 13 overseas smart factories in manufacturing capacity promotion, scenario implementation exploration and territorial compliance operation were systematically analyzed, we hope to share the construction results of our country's intelligent factory at home and abroad with the Global Manufacturing



Enterprises, and provide a useful guide for the digital and intelligent transformation of the vast number of manufacturing enterprises.



# 巴西——徐工高端工程机械智能工厂

## 一、海外工厂整体情况

工厂坐落于巴西米纳斯州包索市，是徐工集团全球化主战略的核心标杆，也是中国工程机械行业在南美地区规模最大的海外制造基地。工厂于 2012 年奠基，2014 年投产，占地 1200 亩，厂房面积 14 万平方米，具备年产挖掘机、装载机、平地机、起重机等各类工程机械 1 万台以上的能力。其中，装载机、平地机、挖掘机等主流产品在南美市场占有率稳居前三，大型矿山设备成功进入国际矿业巨头供应链。

## 二、重点环节智能化建设情况

徐工以“打造海外智能工厂样板”为目标，秉持“精益化、智能化”核心理念，打通“研产供销服财税法”八大业务域，构建了覆盖市场预测、供应链协同、生产制造、质量追溯、仓储物流、销售及经营分析的一体化精益化运营模式。同时，结合巴西本地制造、税务、进口链路及多法人协同特点，形成“计划驱动+精益制造+本地化合规”的运营机制，打造形成具有海外复制价值的高适配、高协同智能工厂运营模式。

### 1. 智能工厂总体架构

以徐工集团总部“智改数转网联”一号工程战略为牵引，工厂基于 4A 架构（业务、应用、技术、数据）重构数字底座，通过纵深推进 8 大转型域、66 项数字化转型任务，成功落地

“4+8+6+2+5”全价值链创新实践。通过引入集团总部 120 项核心业务流程并固化 130 项本地化流程，搭建一体化流程门户；以 ERP 为核心，深度集成 PDM、MDM、CRM、MES、WMS、QMS、IOT 等系统，并打通巴西本地 TAXONE、NFE 等关键财税合规系统，构建统一业务数字化平台，推动运营效率提升超 50%，实现端到端业务闭环与组织协同能级跃升。

全球视角下的本地智慧：全价值链 “4+8+6+2+5” 在巴西的创新与实践



图 1 徐工巴西 “4+8+6+2+5” 全价值链创新实践

## 2. 研发设计：基于集团全球平台的协同研发

工厂构建了覆盖工程机械产品全生命周期的数字化研发体系，实现国内与巴西的协同研发。通过共用 PDM 平台、采用同套三维设计软件，在数据、软件、平台、规则上全面统一，实现通用件与外购件技术参数的互通。巴西团队依托国内开发成果，通过三维模拟验证零部件安装互换性、完成结构调整及热平衡分析等本地化适配，双方分工协作，确保产品性能满足要求。

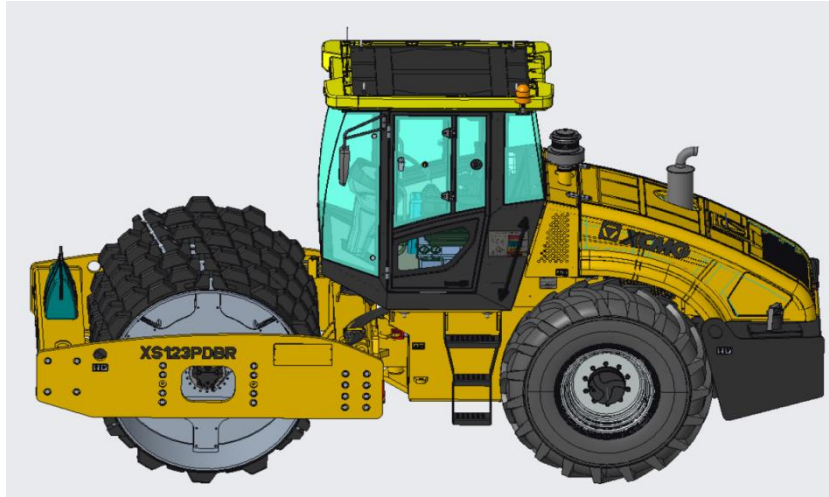
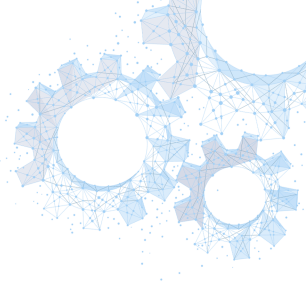


图 2 整机三维辅助设计

### 3. 生产制造：打造精益数智化运营的海外工厂

围绕工程机械多品种、小批量、高度离散的行业特点，构建覆盖下料、焊接、机加工、涂装、装配的全流程生产体系，融合 ERP、MES、WMS、QMS 及 IoT 系统，同时通过多品种柔性排产、设备联网、质量追溯及实时数据分析，实现订单、生产、质量、仓储与服务全链路协同，快速响应巴西市场个性化需求。一是升级智能装备与自动化产线，下料产线结合 SigmaNEST 智能排料系统优化排料方案；焊接产线部署 30 套机器人焊接工作站，集成激光与 3D 视觉寻位系统保障焊接质量；机加工产线采用大型 CNC 加工中心，实现关键结构件 100% 数控加工；涂装产线应用自动循环涂装与静电喷涂技术，实现涂装高效标准化，提升涂层质量；装配产线全面部署伺服扭矩控制系统，实现关键部位螺栓拧紧监控、追溯与异常预警。二是部署数智化系统，逐步打通研发、供应链、制造、质量及仓储全业务链路，形成“数据贯通、业务协同、实时决策”的智能制造体系。MES 系统围绕生产计划、工序报工、装配过程、工时采集及生产追溯，实现生产过程数字

化管控，提升排产效率和现场透明度；IoT 平台通过采集焊接、加工、涂装及装配等关键设备运行数据，对设备状态、能耗、设备综合效率（OEE）及异常预警进行实时分析，提高设备利用率和预防性维护能力；QMS 系统覆盖从来料检验、过程质量、整机下线及售后质量反馈和追溯的各个环节，实现产品全生命周期质量闭环管理；WMS 系统统一管理备件及生产物资库存，结合条码、库位及出入库策略，实现仓储作业标准化、库存实时化及生产配送协同。



图 3 徐工巴西 MES 系统

#### 4. 运营管理：数智一体化运营、智能运维与决策协同

工厂构建以 ERP 为核心的一体化运营平台，集成各类业务系统，贯通订单到交付全流程，实现端到端业务闭环与高效协同，同时满足巴西复杂税务自动计算与合规处理。一是**供应链数字化管理**，搭建覆盖国内产品生产交付、国际运输物流、巴西当地供应链交付的全球供应链三级预警机制，并通过 ERP 系统实现在线管理，形成供应链流程闭环监控与分级响应，提升供应链韧性。二是**产品智能化运维**，依托徐工自研的车联网平台，实现产品实

时监测与故障诊断，并围绕矿山大客户运营需求，打造智慧矿山设备运营平台。通过融合 IoT、5G、卫星互联网、AI 算法及云平台技术，打通设备、施工、调度与服务全业务链路，实现矿山施工全生命周期数字化闭环，形成“设备互联、智能调度、少人化运营、远程化管理”的智慧矿山运营模式。三是智能决策，构建营销服务、生产制造等运营驾驶舱及全球管报智能决策平台，通过数据可视化分析，支撑管理层实时精准决策。同时，搭建面向客户的 AI 服务助手，开展备件、服务等智能化应用，提高订单转化效率和客户满意度。

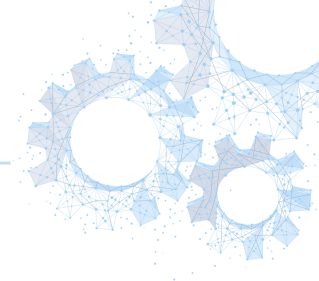


图 4 服务备件驾驶舱

### 三、工厂实施成效

通过研发设计、生产制造、运营管理等全业务链数智化升级，构建高端工程机械智能工厂，成功打造徐工全球化战略的典范标杆。一是效率效益全方位提升，生产效率整体提升 21%、产品不良率下降 5.5%，单位产值能耗下降 15%，结构件单班次产能、人均产出翻倍增长，单车制造成本下降 13.6 个百分点。同时，制造当地化率提升 5%，采购周期缩短 30%以上，有效破解海外供

应链响应慢、周期长的痛点。二是**深度融入本地文化**，中巴团队在项目实施、管理协同和技术交流中实现深度融合，培养了一批本地化数字化与智能制造人才，同时增强了企业国际化运营与跨文化管理能力，有效带动当地就业、税收增长和产业链协同发展。三是**首创海外全价值链数字化贯通模式**，实现主机厂-进出口-海外工厂跨国业务链的实物流、信息流、资金流三位一体统一，通过打造适配海外市场的高柔性智能制造体系，精准匹配南美市场多品种、小批量、定制化需求，实现土方机械产品混线生产，兼顾柔性生产与规模效应，提升敏捷交付能力和客户满意度。



# **Brazil – XCMG High-End Construction Machinery Smart Factory**

## **I. Overview of the Overseas Factory**

Located in Pouso Alegre, Minas Gerais, Brazil, the factory is a flagship benchmark of XCMG Group’s global strategy and the largest overseas manufacturing base of China’s construction machinery industry in South America. Construction began in 2012, and production commenced in 2014. Covering an area of 800,000 m<sup>2</sup> (approx. 1,200 mu) with a workshop floor space of 140,000 m<sup>2</sup>, the factory has an annual production capacity of over 10,000 units of various construction machinery, including excavators, loaders, motor graders, and cranes. Among these, mainstream products such as loaders, motor graders, and excavators consistently rank among the top three in market share in South America, while large-scale mining equipment has successfully entered the supply chains of global mining giants.

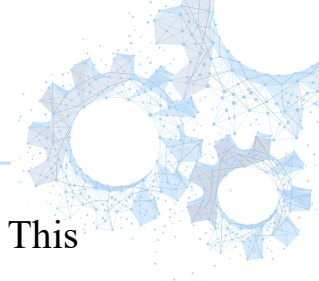
## **II. Status of Intelligent Construction in Key Areas**

Guided by the goal of “building a model overseas Smart Factory” and adhering to the core philosophy of “lean and smart,” XCMG has integrated eight major business domains (R&D, production,

procurement, sales, service, finance, taxation, legal) and established an integrated lean operation model covering market forecasting, supply chain collaboration, manufacturing, quality traceability, warehousing and logistics, sales and service, and business analysis. Additionally, taking into account Brazil's local manufacturing, tax regimes, import channels, and multi-entity collaboration characteristics, the factory has developed an operation mechanism combining “plan-driven, lean manufacturing, and local compliance,” creating a highly adaptable and collaborative Smart Factory operation model that can be replicated in other overseas factories.

## **1. Overall Architecture of the Smart Factory**

Driven by XCMG Group's “Digitalization, Smartization, and Connectivity” No. 1 Project strategy, the factory has rebuilt its digital foundation based on the 4A architecture (business, application, technology, data). By deeply advancing eight transformation domains and 66 digital transformation tasks, it has successfully implemented the “4+8+6+2+5” full-value-chain innovation practice. The factory has introduced 120 core business processes from the Group and solidified 130 local processes, building an integrated process portal. With ERP as the core, it deeply integrates PDM, MDM, CRM, MES, WMS, QMS, IoT, and other systems, while connecting critical local



Brazilian compliance systems such as TAXONE and NFE. This unified digital business platform has improved operational efficiency by over 50%, achieving end-to-end business and a leap in organizational collaboration.

**Global Vision with Local Wisdom: Innovation and Practice of the Full Value Chain “4+8+6+2+5” in Brazil**

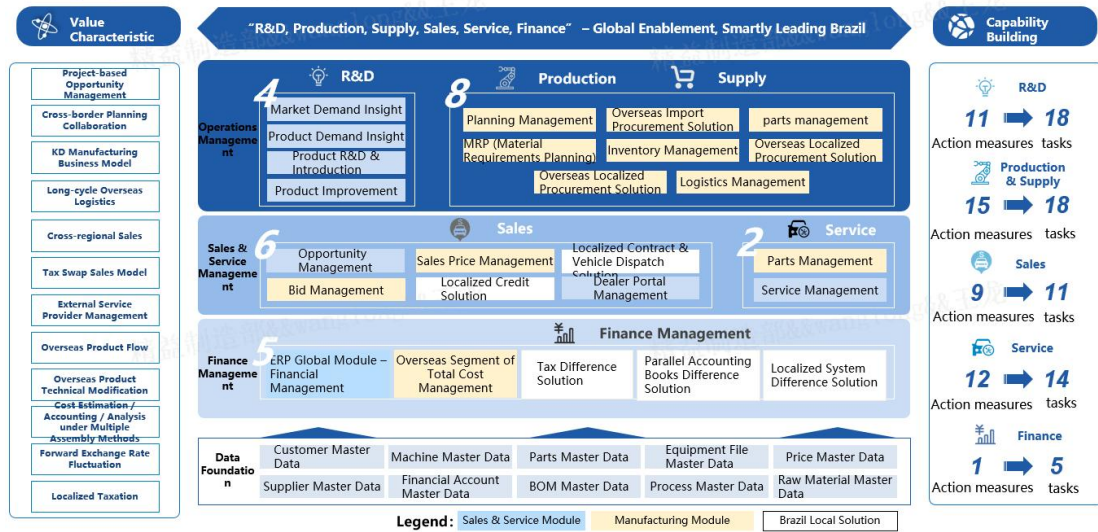


Figure 1: XCMG Brazil “4+8+6+2+5” Full-Value-Chain Innovation Practice

## 2. R&D and Design: Collaborative R&D Based on the Group’s Global Platform

The factory has established a digital R&D system covering the entire lifecycle of construction machinery products, enabling collaborative R&D between China and Brazil. By sharing the PDM platform and using the same 3D design software, data, software, platforms, and rules are fully unified, allowing interchangeability of technical parameters for general and purchased parts. The Brazilian team relies on development results from China, conducting 3D simulations to

verify part interchangeability, structural adjustments, thermal balance analysis, and other localization adaptations, ensuring product performance meets requirements.



Figure 2: 3D Aided Design of Complete Machine

### **3. Production and Manufacturing: Building an Overseas Factory with Lean Digital and Intelligent Operations**

Given the industry characteristics of multi-variety, small-batch, and highly discrete manufacturing, the factory has built a full-process production system covering blanking, welding, machining, painting, and assembly, integrating ERP, MES, WMS, QMS, and IoT systems. Through multi-variety flexible scheduling, equipment networking, quality traceability, and real-time data analysis, it enables end-to-end collaboration across orders, production, quality, warehousing, and service, rapidly responding to the personalized demands of the Brazilian market. Key initiatives include: **Upgraded smart**



**equipment and automated lines:** The blanking line uses SigmaNEST intelligent nesting; the welding line deploys 30 robotic welding workstations with laser and 3D vision guidance systems; the machining line uses large CNC machining centers achieving 100% CNC machining of key structural parts; the painting line applies automatic circulation and electrostatic spraying for high efficiency and quality; the assembly line fully deploys servo torque control systems for monitoring, traceability, and early warning of critical bolted joints. **Deployment of digital and intelligent systems:** Gradually connect R&D, supply chain, manufacturing, quality, and warehousing to form a smart manufacturing system featuring data connectivity, business collaboration, and real-time decision-making. MES enables digital control of production planning, job reporting, assembly processes, labor hour collection, and traceability, improving scheduling efficiency and shop-floor transparency. The IoT platform collects operational data from key equipment (welding, machining, painting, assembly) for real-time analysis of equipment status, energy consumption, OEE, and anomaly alerts, boosting utilization and predictive maintenance. QMS covers incoming inspection, in-process quality, final machine testing, and after-sales quality feedback and traceability, achieving closed-loop quality management throughout the product lifecycle. WMS manages

spare parts and production material inventory with barcodes, bin locations, and put-away/retrieval strategies, enabling standardized warehousing, real-time inventory, and production delivery coordination.



Figure 3: XCMG Brazil MES System

#### 4. Operations Management: Integrated Digital and Intelligent Operations, Intelligent O&M, and Collaborative Decision-Making

The factory has built an integrated operations platform with ERP at its core, integrating various business systems to connect the entire order-to-delivery process, achieving end-to-end business closure and efficient collaboration, while also handling complex Brazilian tax calculations and compliance. Specifics include: **Digital supply chain management:** A three-level global supply chain early-warning mechanism covering domestic production and delivery, international transport, and local Brazilian supply chain, managed online via ERP,



enabling closed-loop monitoring and tiered response to enhance supply chain resilience. **Smart product O&M:** Leveraging XCMG’s proprietary telematics platform, the factory enables real-time product monitoring and fault diagnosis, and has built a smart mining equipment operations platform for key mining customers. By integrating IoT, 5G, satellite internet, AI algorithms, and cloud platform technologies, it connects equipment, construction, dispatching, and service, forming a digital closed loop for the entire mining lifecycle – a smart mining operation model characterized by “equipment connectivity, intelligent dispatching, less manned operation, and remote management.” **Intelligent decision-making:** The factory has built operations dashboards for marketing, service, and manufacturing, as well as a global management reporting and intelligent decision-making platform. Data visualization supports real-time, accurate decisions by management. Additionally, an AI-powered customer service assistant has been launched for intelligent parts and service applications, improving order conversion efficiency and customer satisfaction.



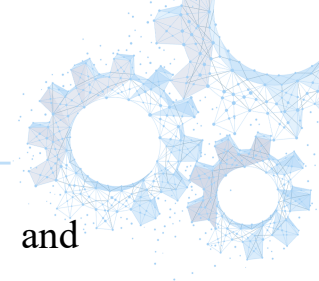
Figure 4: Service Parts Dashboard

### III. Implementation Effectiveness of the Overseas Factory

Through digital and intelligent upgrades across the entire business chain – R&D, production, operations management – the factory has built a high-end construction machinery Smart Factory and become a benchmark for XCMG’s global strategy. Key results include:

**Comprehensive improvement in efficiency and effectiveness:** Overall production efficiency increased by 21%, product defect rate decreased by 5.5%, energy consumption per unit output value dropped by 15%, output per shift for structural parts and per capita output doubled, and manufacturing cost per machine fell by 13.6 percentage points. Meanwhile, the localization rate of manufacturing rose by 5%, procurement lead time shortened by over 30%, effectively addressing the slow response and long lead times common in overseas supply chains.

**Deep integration into local culture:** The China-Brazil teams have achieved deep integration



through project implementation, management collaboration, and technical exchanges, cultivating a group of local digital and intelligent manufacturing talents. This has also strengthened the company's international operations and cross-cultural management capabilities, while boosting local employment, tax revenues, and industrial chain development. **Pioneering overseas full-value-chain digital integration model:** The factory has achieved unified physical, information, and capital flows across the multi-national business chain of OEM – import/export – overseas factory. By creating a highly flexible smart manufacturing system tailored to overseas markets, it precisely meets the diverse, small-batch, customized demands of the South American market, enabling mixed-line production of earthmoving machinery products while balancing flexibility and economies of scale, thus improving agile delivery capability and customer satisfaction.

## 巴西——亚普汽车零部件智能工厂

### 一、海外工厂整体情况

工厂坐落于巴西南大河州，是亚普汽车部件股份有限公司（以下简称“亚普股份”）全球化战略的核心标杆，也是中国汽车零部件行业在南美地区的重要制造基地。工厂于 2017 年奠基、2019 年投产，占地 17.2 亩，厂房面积 9492.53 平方米，主营汽车储能系统核心部件的研发与制造，服务于南美及全球主流汽车品牌。面对南美市场多品种、小批量的定制化需求及复杂的供应链环境，工厂确立了“依托国内卓越级智能工厂成果，打造海外柔性智造样板”的建设目标，成功将中国智能制造标准在海外落地生根，整体建设水平位居巴西吹塑行业前列。

### 二、重点环节智能化建设情况

工厂创新构建了“五维”柔性智造体系，通过深度融合物联网与 AI 技术，实现从研发到生产的全流程数字化闭环，打造出具备快速换型能力的柔性自动化标杆。

#### 1. 智能工厂总体架构

工厂依托集团“国家卓越级智能工厂”的成熟技术架构，构建了“五维”柔性智造体系。该体系以 SAP 为核心，深度集成 MES、PLM、VM 等系统，打通与国内总部的数据链路，实现全球协同。在硬件层，部署了工业机器人、智能传感器及视觉检测设备，实现吹塑、焊接、修边等全工序的自动化覆盖。在平台层，

通过工业以太网搭建统一的数据底座，使设备数据自动采集率达95%以上；同时，通过独立跨境数据通道，实现与国内总部的实时互联与数据加密存储，确保全球业务协同与数据安全可控。在应用层，构建“研产供销”一体化协同平台，实现从订单到交付的全流程闭环管理。

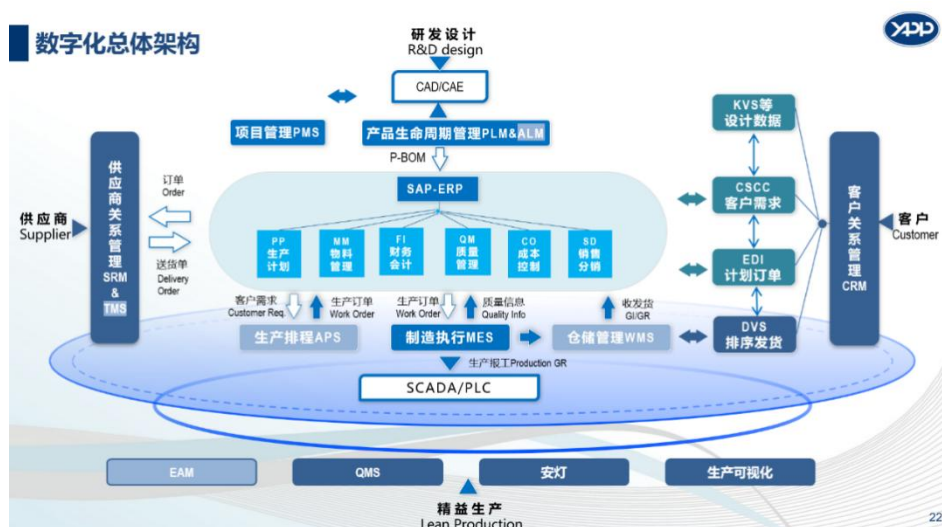


图1 亚普巴西数字化总体架构

## 2. 研发设计：全球研发协同，虚拟验证降本

工厂构建了全球协同的研发设计体系，实现研发数据与国内总部的实时同步。一是**研发协同化**。打破海外研发孤岛，基于PLM（产品生命周期管理系统）构建全球统一的研发平台，打通巴西工厂与国内研发中心、客户端的数据链路，实现设计成果的统一归档与版本可控，确保海外工厂与国内技术标准严格一致，显著缩短新品导入周期。二是**工艺虚拟验证**。创新采用“国内虚拟验证+海外现场调试”模式。利用Blow view工艺仿真工具模拟燃油箱吹塑成型全过程，提前识别制造缺陷；利用Miot.VC工业仿真软件对设备运动路径及节拍进行虚拟调试。虚实结合模式

大幅降低了现场调试难度与设备成本，确保了工艺方案的成熟度。

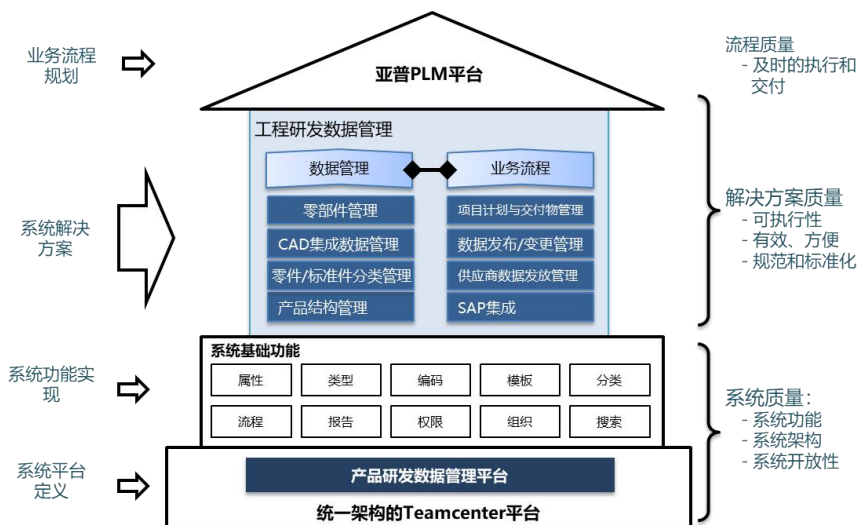


图 2 亚普 PLM 平台方案

### 3. 生产制造：柔性产线一键换型，AI 质检精准追溯

围绕汽车零部件多品种、高切换、小批量的制造特点，工厂构建了高度自动化的柔性生产体系。一是**柔性自动化生产线**。对吹塑、水冷、修边、焊接等全工序进行整体布局优化，采用工业机器人模组化部署与标准化工装快换结构，并引入智能化调度系统。该系统内置工艺参数数据库，订单变更时可自动匹配参数并指挥机器人调用程序，实现“一键换型”，有效解决多品种混线生产难题。二是**AI 视觉精准检测**。工厂搭建智能化视觉检测平台，融合深度学习算法，经过海量样本训练后具备强自适应能力。该平台可实现对焊件有无、螺钉缺失、关键尺寸等特征的全自动非接触式检测，检测数据实时上传并绑定产品条码，形成完整质量追溯链条。

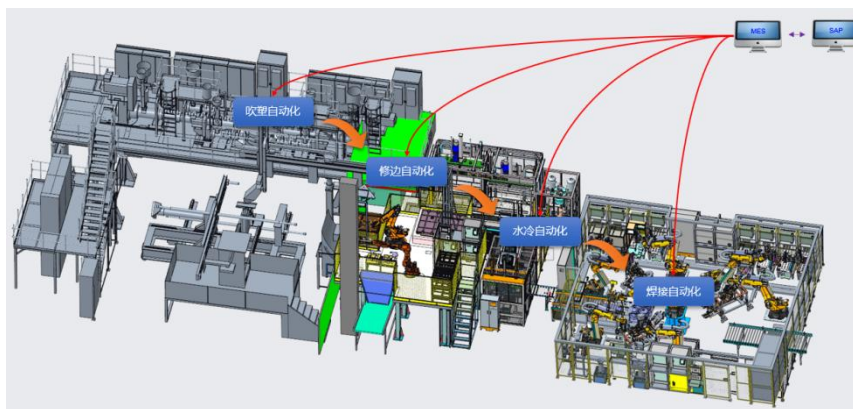
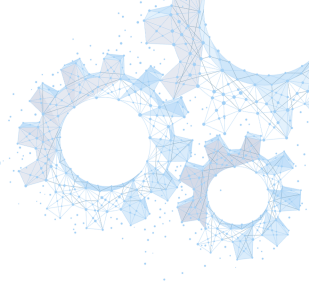


图 3 全自动柔性生产线

#### 4. 运营管理：产供销一体化协同

工厂构建了数据驱动的精益运营管理体系，实现了从“经验管理”向“数据驱动”的转变。一是产销协同一体化。通过 ERP 与 MES、PLM 系统深度集成，打通销售、生产、采购、库存全链路数据流，MRP 系统自动生成最优计划，降低库存积压与待料风险，实现全球供应链的敏捷响应。二是经营决策智能化。依托大数据平台整合多维度数据，提供实时可视化分析报告，以数据分析为基础，实现精准市场预判与资源优化调配，为科学决策提供有力支撑。三是精益管理与服务升级。全流程数据追溯优化生产节拍，基于产品全生命周期数据提供精准售后支持，提升客户满意度。

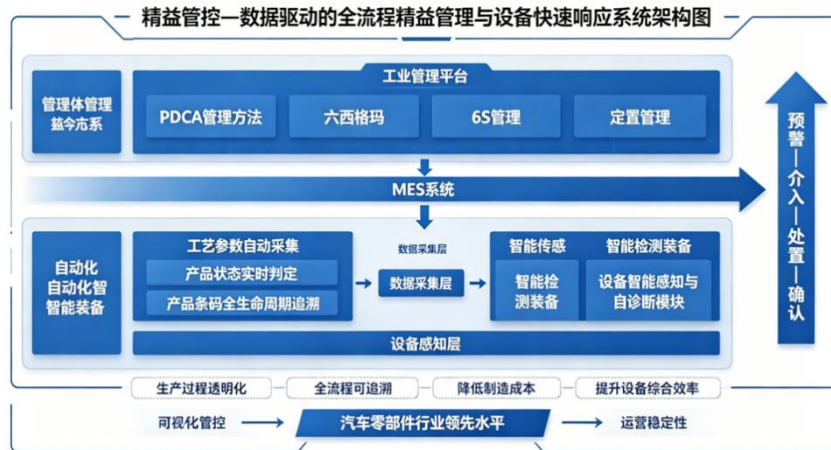
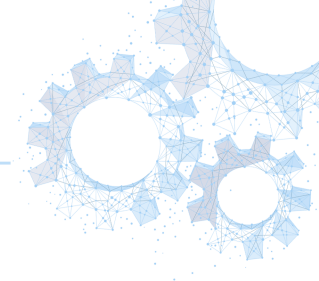


图 4 精益管理与快速响应系统架构图

### 三、工厂实施成效

一是**效率显著提升**。通过柔性产线与人机协同，打破生产瓶颈，生产效率提升 2.22%，设备综合利用率提升 2.21%，产能与交付能力有效释放。二是**质量更加稳定**。依托 AI 视觉智检与全流程追溯，实现关键特征全检，产品不良率显著下降，一次合格率提升 0.6%以上。三是**成本有效降低**。通过数字化运营与精益管理，优化物料规划与人员配置，减少设备故障与维修成本，实现单件人工成本整体下降约 21%。四是**绿色低碳转型**。依托智能调度与精准控制，资源综合利用率提升 6.72%，能源与物料损耗明显减少，推动生产向绿色低碳转型。



## **Brazil—Yapp Auto Parts Smart Factory**

### **I. Overview of the Overseas Factory**

The factory is located in Rio Grande do Sul, Brazil. It serves as a core benchmark of YAPP Automotive Parts Co., Ltd. (hereinafter referred to as “YAPP”) in its globalization strategy and represents an important manufacturing base for the Chinese automotive parts industry in South America.

The factory broke ground in 2017 and commenced production in 2019. It occupies a land area of 17.2 mu (approximately 11,467 square meters) with a built-up plant area of 9,492.53 square meters. Its primary business focuses on the research and development and manufacturing of core components for automotive energy storage systems, serving mainstream automotive brands across South America and globally.

In response to the South American market’s demand for multi-variety, small-batch customized production and the complex supply chain environment, the factory established the strategic objective of “leveraging the achievements of its exemplary domestic intelligent factories to build an overseas model of flexible intelligent manufacturing.” It has successfully localized advanced Chinese

intelligent manufacturing standards overseas, with its overall construction level ranking among the forefront of Brazil's blow molding industry.

## **II. Status of Intelligent Construction in Key Areas**

The factory has innovatively established a “Five-Dimensional” flexible intelligent manufacturing system. By deeply integrating Internet of Things (IoT) and Artificial Intelligence (AI) technologies, it has achieved a fully digitalized closed-loop process spanning from R&D to production, thereby creating a benchmark for flexible automation with rapid changeover capabilities.

### **1. Overall Architecture of the Smart Factory**

The factory has built the “Five-Dimensional” flexible intelligent manufacturing system by leveraging the Group's mature technical architecture of its “Outstanding Smart Factory.”

This system takes SAP as its core and deeply integrates MES, PLM, VM, and other systems, thereby establishing a seamless data link with the domestic headquarters and realizing global collaboration.

At the hardware layer, the factory has deployed industrial robots, intelligent sensors, and vision inspection equipment, achieving full-



process automation coverage for blow molding, welding, trimming, and other operations.

At the platform layer, a unified data foundation has been constructed through industrial Ethernet, enabling an automatic equipment data collection rate of over 95%. At the same time, a dedicated cross-border data channel has been established to realize real-time interconnection with the domestic headquarters and encrypted data storage, ensuring controllable global business collaboration and data security.

At the application layer, an integrated collaborative platform covering “R&D, Production, Supply, and Sales” has been built, achieving full-process closed-loop management from order to delivery.

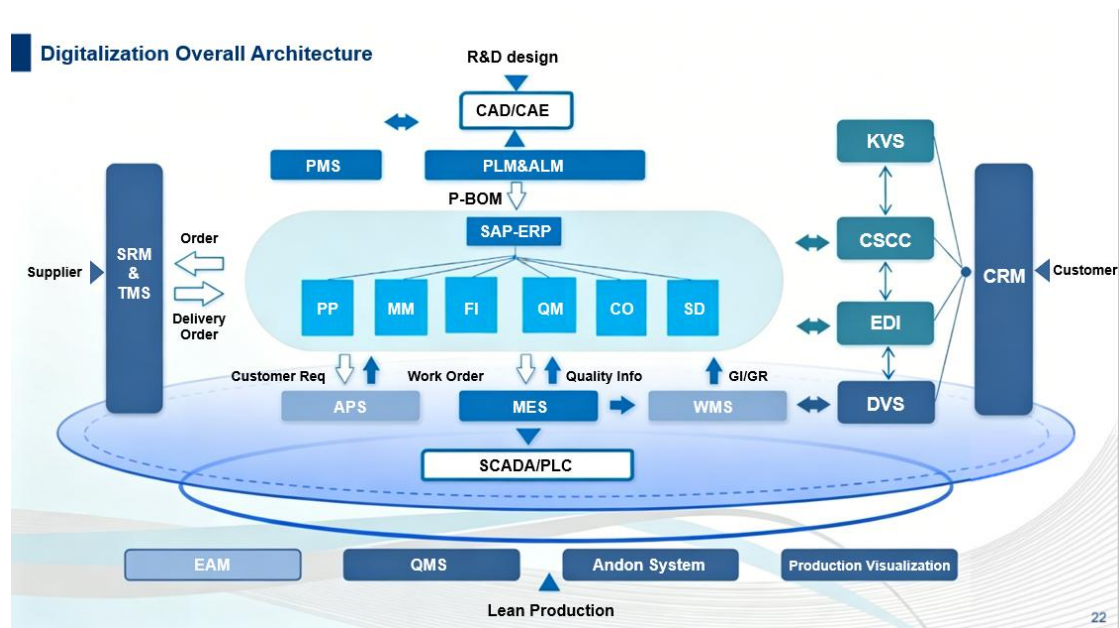


Figure 1: Overall Digital Architecture of YAPP Brazil

## **2. R&D and Design: Global Collaborative R&D and Virtual Validation for Cost Reduction**

The factory has established a globally collaborative R&D and design system, achieving real-time synchronization of R&D data with the domestic headquarters.

**First, R&D collaboration.** By breaking down overseas R&D silos, the factory has built a globally unified R&D platform based on PLM (Product Lifecycle Management). This connects the data links among the Brazil factory, domestic R&D centers, and clients, realizing unified archiving and version control of design outcomes. It ensures strict consistency between the overseas factory's technical standards and those of the domestic headquarters, while significantly shortening the new product introduction cycle.

**Second, process virtual validation.** The factory has innovatively adopted a “domestic virtual validation + overseas on-site commissioning” model. It utilizes the BlowView process simulation tool to simulate the entire blow molding process of fuel tanks and identify potential manufacturing defects in advance. It also employs the Miot.VC industrial simulation software to perform virtual debugging of equipment motion paths and cycle times. This virtual-physical integration model substantially reduces the difficulty and



cost of on-site commissioning while ensuring the maturity of process solutions..

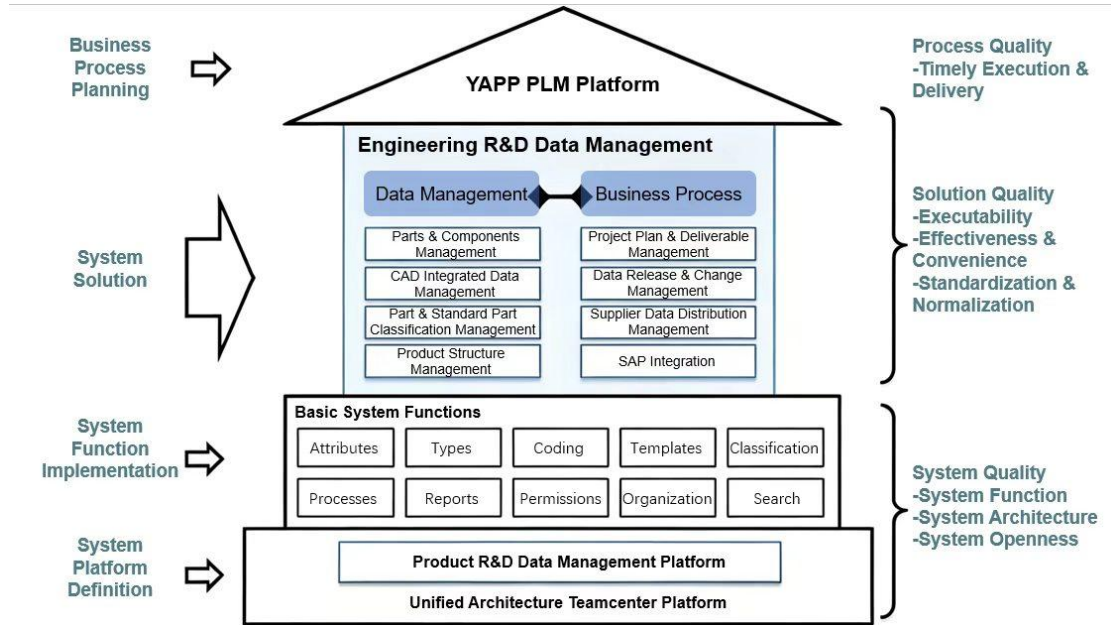


Figure 2: YAPP PLM Platform Solution

### 3. Production and Manufacturing: One-Click Changeover on Flexible Production Lines and Precise Traceability via AI Quality Inspection

The factory has established a highly automated flexible production system tailored to the manufacturing characteristics of automotive parts—multi-variety, high-changeover, and small-batch production.

**First, flexible automated production lines.** The overall layout for the full processes of blow molding, water cooling, trimming, welding, and other operations has been optimized. Modular deployment of industrial robots and standardized quick-change tooling structures are

adopted, along with the introduction of an intelligent scheduling system. This system incorporates a built-in process parameter database; upon order changes, it automatically matches parameters and directs robots to call the corresponding programs, achieving “one-click changeover” and effectively resolving the challenges of multi-variety mixed-line production.

**Second, AI vision-based precise inspection.** The factory has built an intelligent vision inspection platform that integrates deep learning algorithms. After training on massive sample datasets, the platform demonstrates strong adaptability. It enables fully automatic, non-contact detection of features such as the presence or absence of weldments, missing screws, and critical dimensions. Inspection data is uploaded in real time and bound to product barcodes, forming a complete quality traceability chain.

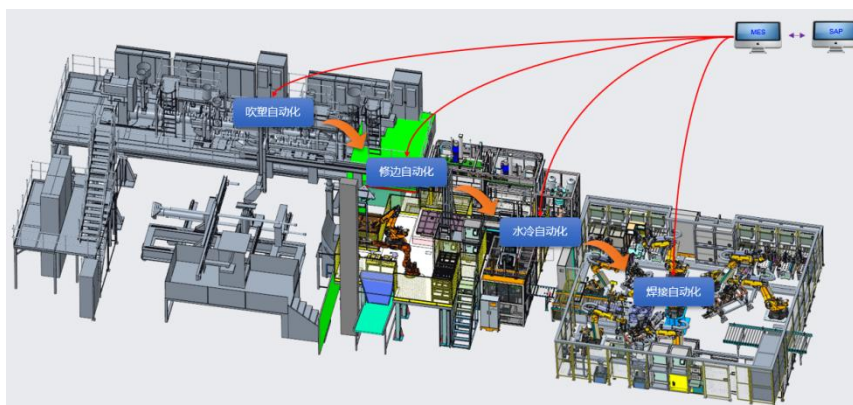
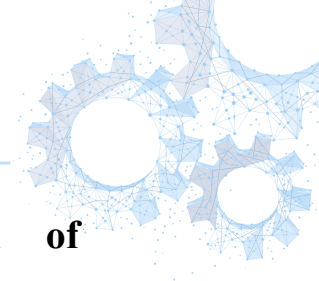


Figure 3: Fully Automated Flexible Production Lines



#### **4. Operations Management: Integrated Collaboration of Production, Supply, and Sales**

The factory has established a data-driven lean operations management system, successfully transitioning from “experience-based management” to “data-driven management.”

**First, integrated production-sales collaboration.** Through deep integration of the ERP, MES, and PLM systems, the factory has connected the full-chain data flows across sales, production, procurement, and inventory. The MRP system automatically generates optimal plans, reducing inventory backlog and material shortage risks while enabling agile response of the global supply chain.

**Second, intelligent business decision-making.** Leveraging a big data platform to integrate multi-dimensional data, the factory provides real-time visualization analysis reports. This data-driven approach enables precise market forecasting and optimized resource allocation, offering strong support for scientific decision-making.

**Third, lean management and service upgrading.** Full-process data traceability is used to optimize production takt time, while product full-lifecycle data provides precise after-sales support, thereby enhancing customer satisfaction..

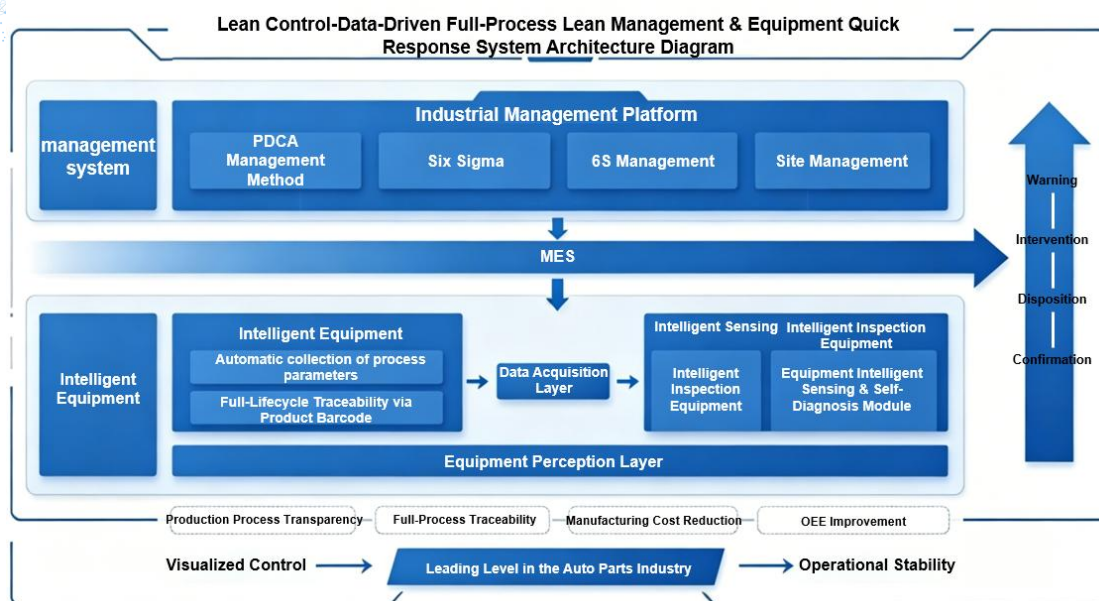
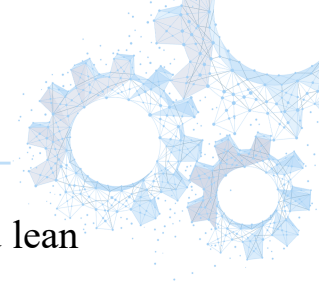


Figure 4: Lean Management and Rapid Response System Architecture Diagram

### III. Implementation Effectiveness of the Overseas Factory

**First, significant improvement in efficiency.** Through flexible production lines and human-machine collaboration, production bottlenecks have been eliminated, resulting in a 2.22% increase in production efficiency and a 2.21% increase in overall equipment effectiveness (OEE). Production capacity and delivery capabilities have been effectively released.

**Second, greater quality stability.** Leveraging AI vision-based intelligent inspection and full-process traceability, 100% inspection of critical features has been achieved. The product defect rate has decreased significantly, with the first-pass yield improved by more than 0.6%.



**Third, effective cost reduction.** Through digital operations and lean management, material planning and workforce allocation have been optimized, equipment failures and maintenance costs have been reduced, resulting in an overall decrease of approximately 21% in per-piece labor costs.

**Fourth, green and low-carbon transformation.** Relying on intelligent scheduling and precise control, the comprehensive resource utilization rate has increased by 6.72%, with notable reductions in energy and material losses, driving the production process toward a green and low-carbon transition.

## 柬埔寨——双星轮胎智能工厂

### 一、海外工厂整体情况

工厂坐落于柬埔寨东北部桔井省 UBE 斯努经济特区，地理位置优越，交通便利，位于规划建设中的泛亚铁路东线柬埔寨至越南途经点。工厂于 2023 年 5 月动工，2024 年 9 月正式投产。工厂总占地面积约 40 万 m<sup>2</sup>，建筑面积 18.5 万 m<sup>2</sup>，设计年产高性能子午线轮胎 850 万套，其中全钢子午线轮胎 150 万套。

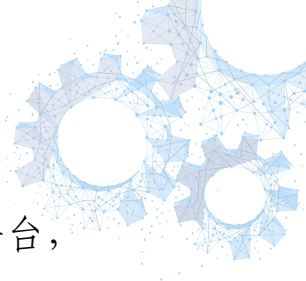


图 1 双星柬埔寨轮胎智能工厂厂区全貌实景图

### 二、重点环节智能化建设情况

双星集团以智慧转型为引领，建成了全球轮胎行业全流程“工业 4.0”智能化工厂，并将这一成功模式复制到海外，围绕“数字化驱动、精益化运营、智能化提升”总体目标，在柬埔寨建成又一座轮胎智能工厂。

#### 1. 智能工厂总体架构



工厂以 ERP (SAP) 和 MES 为核心，构建统一信息化平台，覆盖生产计划管理、生产过程控制、质量管理、设备管理等关键业务，实现从订单下达到生产执行、再到入库交付的全流程数据贯通。



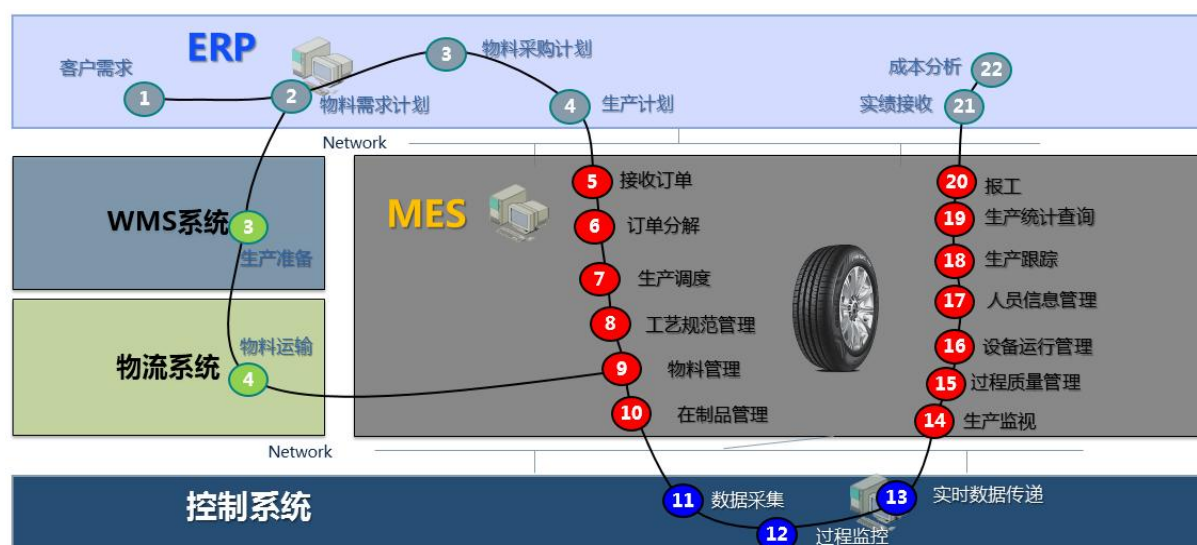
图 2 双星柬埔寨轮胎智能工厂整体架构图

工厂充分利用工业互联网、微服务、云架构、工业大数据、机器学习等信息技术，构建了轮胎制造物联网平台。该平台实现了从轮胎制造到使用全过程的实时数据采集、高效安全存储、多源异构数据集成与跨业务协同管理，具备大数据分析处理能力，助力智能工厂实现了生产数据的自动采集、智能传输以及大数据驱动的智能分析应用，推动传统生产模式向数据驱动转型。

## 2. 生产制造：生产数据驱动过程预防，MEP 协同破解行业难题

生产制造环节是智能化建设的核心，重点围绕“数据采集—过程控制—能力分析—调度优化”展开。工厂以 MES 系统为核心，实现生产订单管理、工序执行控制、条码追溯及过程数据采

集，对生产订单、工艺参数、质量数据及设备运行信息进行统一管理，实现生产过程的可视化管理，为生产运行提供基础数据支撑。采用双星独创的 **MEP 智能信息匹配系统**，实现物、人、设备、位置的协同作业，成功解决了全球范围内以液体和粉体为原料无法实现全流程制造的行业难题。在**成型、硫化、检测等关键工序**，通过 PLC 及工业网络实现设备数据自动采集，系统对关键数据进行实时分析，提高生产过程透明度，为生产调度、质量管理及持续改进提供数据依据。围绕**关键质量控制点**，建立以 **CPK 为核心的过程能力评价体系**，对关键工艺参数进行实时采集与统计分析，当过程能力异常时自动触发预警机制，实现由传统“事后检验”向“过程预防控制”转变，显著提升产品一致性。此外，在**成品物流环节**，建设成品胎自动化输送分拣线，实现轮胎从生产完成到分拣区域的自动输送与分类处理。系统根据规则自动分配流向，减少人工搬运强度，提高物流效率与现场作业规范化水平。



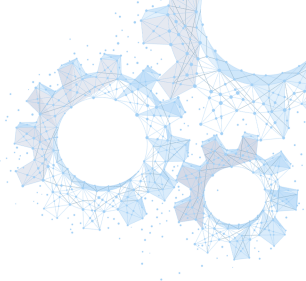


图3 工厂生产制造智能系统架构图

### 3. 运营管理：精准营销驱动业务优化

推行“S2C”（从供应链到消费者）模式，利用物联网轮胎和 CRM 系统等大数据技术，深入挖掘消费者的购买行为、偏好以及需求趋势，从而制定个性化精准营销方案。该模式以前端用户需求驱动后端研发、工艺、制造、采购等系统，同时打通从双星轮胎到其他品牌轮胎、再到汽车后市场产品和服务的共享链路。在此基础上，打造集产品体验、销售、安装、服务于一体的线上线下一体化门店，提供优质的汽车后市场解决方案，持续创造需求。

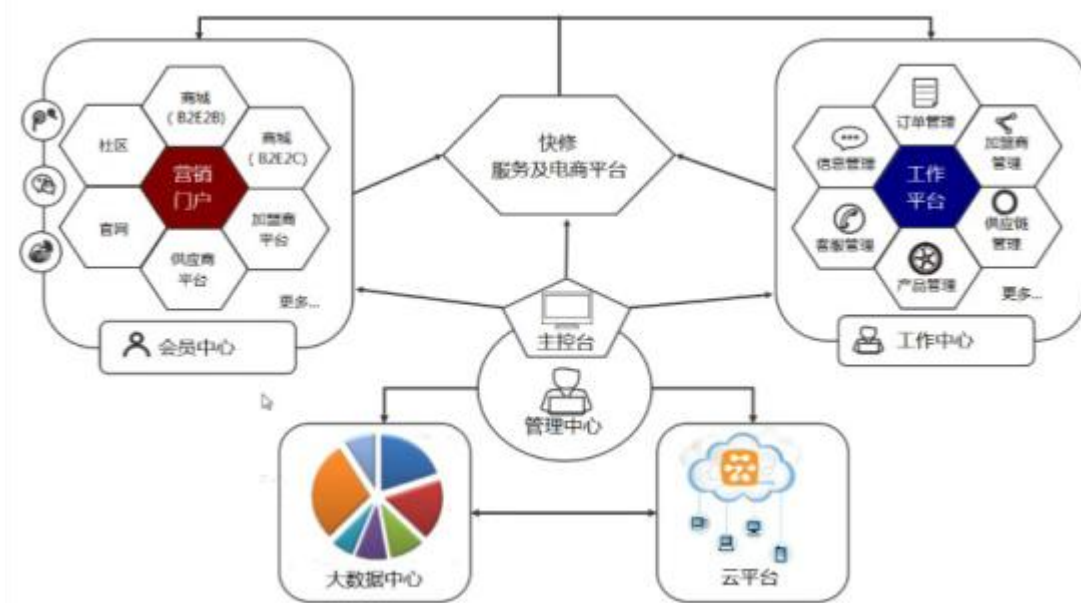


图4 精准营销运营管理架构图

### 三、工厂实施成效

一是生产效率方面，通过生产过程可视化与调度优化，整体生产效率提升约 40%，物流效率提升约 30%，生产节拍更加稳定，现场作业更加规范有序。二是运营成本方面，自动化分拣与系统化管理减少人工操作强度，整体用工减少约 10%，运营成本

降低约 30%。三是产品质量方面，不良品率下降约 30%，一次合格率提升 20%以上。四是库存管理方面，库存准确率提升至 98%以上，有效支撑经营决策。五是绿色安全方面，单位产品能耗降低 30%以上、安全事故率降低 93.3%，为连续生产提供有力保障。工厂采用双星自主研发 MEP 智能信息匹配系统，实现物、人、设备、位置的智能信息匹配，解决了液体/粉体原料全流程自动化难题，单班次产能提升 150%。此外，工厂形成了海外智能工厂模块化高效复制模式，工厂采用“先信息化、再智能化”的实施策略和自主研发的“模块化智造系统”，通过快速复制国内智能工厂经验，构建了适用于海外的信息化建设路径，实现了从产品输出向“技术标准输出”的转型。



## Cambodia—Doublestar Tire Smart Factory

### I. Overview of the Overseas Factory

The factory is located in the UBE Snoul Special Economic Zone, Kampong Cham Province, northeastern Cambodia. It enjoys a superior geographical position and convenient transportation, situated at the planned transit point of the Eastern Line of the Pan-Asian Railway from Cambodia to Vietnam.

The factory broke ground in May 2023 and officially commenced production in September 2024. It covers a total land area of approximately 400,000 m<sup>2</sup> with a built-up area of 185,000 m<sup>2</sup>. The designed annual production capacity is 8.5 million high-performance radial tires, including 1.5 million all-steel radial tire.



Figure 1: XCMG Brazil “4+8+6+2+5” Full-Value-Chain Innovation Practice

## II. Status of Intelligent Construction in Key Areas

Guided by intelligent transformation, Double Star Group has established a full-process “Industry 4.0” Smart Factory in the global tire industry and successfully replicated this model overseas. Centered on the overall objectives of “digital-driven, lean operations, and intelligent enhancement,” the Group has built another intelligent tire factory in Cambodia.

### 1. Overall Architecture of the Smart Factory

The factory has established a unified information platform with ERP (SAP) and MES as its core, covering key business areas such as production planning management, production process control, quality management, and equipment management. This achieves full-process data connectivity from order placement to production execution and subsequently to warehousing and delivery..

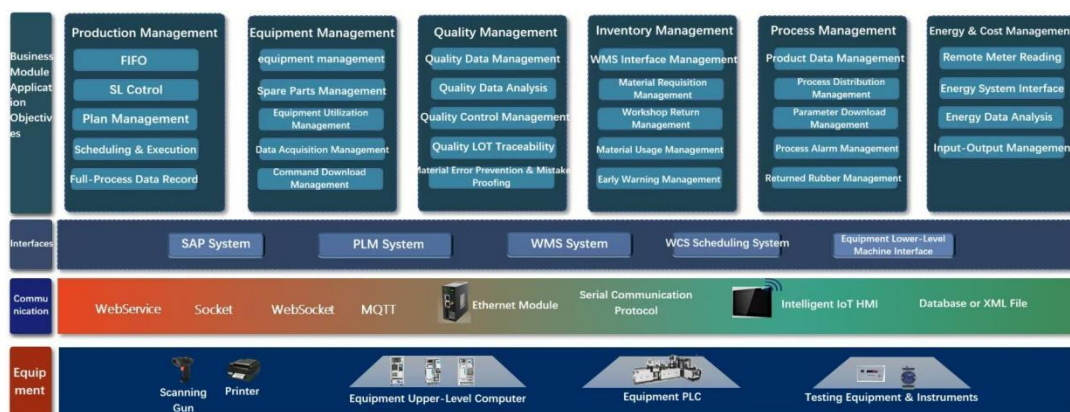




Figure 2: Overall Architecture Diagram of Double Star Cambodia Intelligent Tire Factory

The factory has fully leveraged advanced information technologies such as the Industrial Internet, microservices, cloud architecture, industrial big data, and machine learning to build a tire manufacturing IoT platform.

This platform achieves real-time data collection, efficient and secure storage, multi-source heterogeneous data integration, and cross-business collaborative management throughout the entire process from tire manufacturing to usage. It possesses big data analysis and processing capabilities, enabling the Smart Factory to realize automatic production data collection, intelligent transmission, and big data-driven intelligent analysis applications, thereby driving the transformation of traditional production models toward data-driven operations.

## **2. Production and Manufacturing: Data-Driven Process Prevention and MEP Collaboration to Solve Industry Challenges**

Production and manufacturing constitute the core of Smart Factory construction, with a primary focus on the closed loop of “data collection—process control—capability analysis—scheduling optimization.”

The factory takes the MES system as its core, realizing production order management, process execution control, barcode traceability, and real-time process data collection. It centrally manages production orders, process parameters, quality data, and equipment operation information, achieving visualized management of the production process and providing foundational data support for production operations.

The factory has adopted Double Star's proprietary MEP Intelligent Information Matching System, which enables collaborative operations among materials, personnel, equipment, and locations. This has successfully solved a long-standing global industry challenge: the inability to achieve full-process manufacturing using liquid and powder raw materials.

In key processes such as tire building, vulcanization, and inspection, equipment data is automatically collected through PLC and industrial networks. The system performs real-time analysis of critical data, enhancing production process transparency and providing a data basis for production scheduling, quality management, and continuous improvement.

Centered on critical quality control points, a process capability evaluation system based on CPK has been established. Key process



parameters are collected and statistically analyzed in real time; when process capability anomalies are detected, an automatic early-warning mechanism is triggered. This realizes the transformation from traditional “post-inspection” to “process prevention and control,” significantly improving product consistency.

In addition, in the finished goods logistics stage, an automated conveying and sorting line for finished tires has been constructed, enabling automatic transport and classification of tires from the end of production to the sorting area. The system automatically assigns flow directions according to preset rules, reducing manual handling intensity, improving logistics efficiency, and enhancing the standardization of on-site operations.

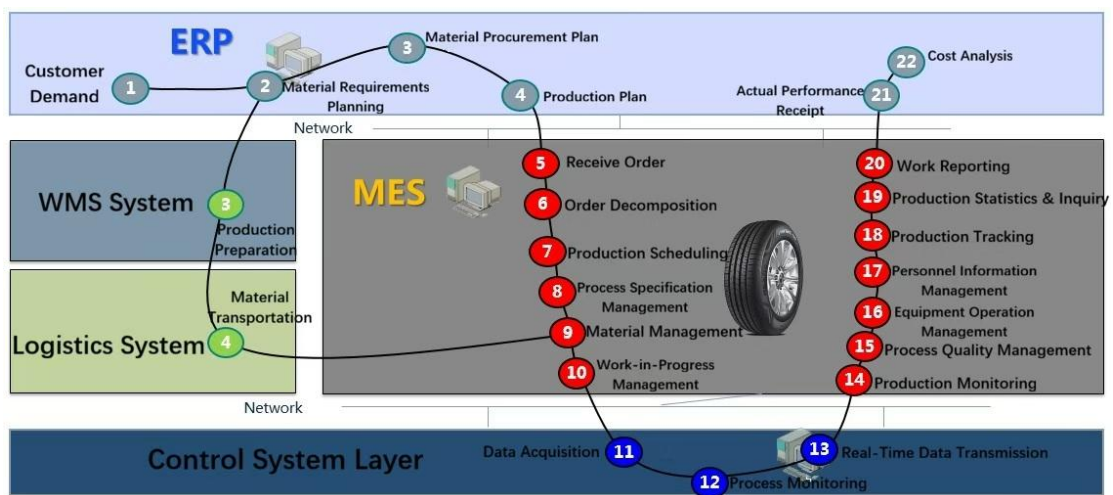


Figure 3: Intelligent Production and Manufacturing System Architecture Diagram

### 3. Operations Management: Precision Marketing-Driven Business Optimization

The factory has implemented the “S2C” (Supply to Consumer) model, leveraging big data technologies such as IoT-enabled tires and the CRM system to deeply analyze consumer purchasing behavior, preferences, and demand trends, thereby formulating personalized precision marketing plans. This model drives the back-end R&D, process, manufacturing, procurement, and other systems with front-end user demand, while establishing a shared linkage from Double Star tires to other brand tires and extending to automotive aftermarket products and services.

On this basis, the factory has developed integrated online and offline stores that combine product experience, sales, installation, and service, providing premium automotive aftermarket solutions and continuously creating new demand.

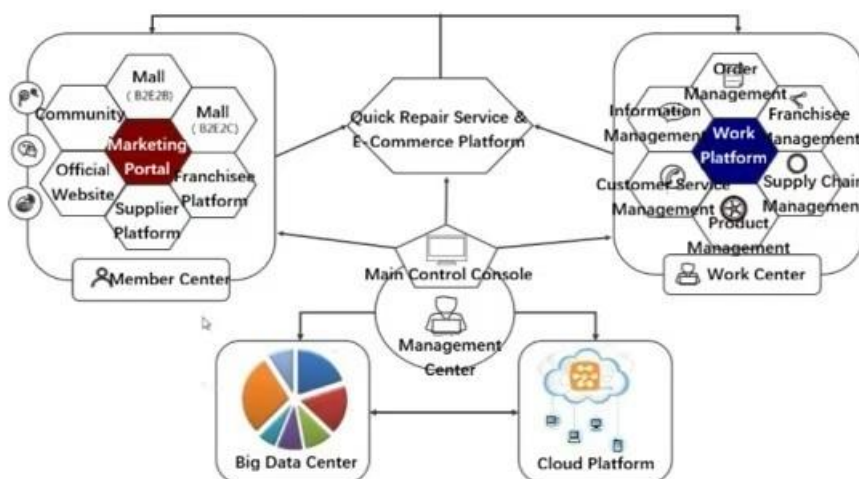


Figure 4: Precision Marketing and Operations Management Architecture Diagram

### III. Implementation Effectiveness of the Overseas Factory



**First, in terms of production efficiency:** Through visualization of the production process and scheduling optimization, overall production efficiency has increased by approximately 40%, logistics efficiency by approximately 30%, production takt time has become more stable, and on-site operations have become more standardized and orderly.

**Second, in terms of operating costs:** Automated sorting and systematic management have reduced manual operation intensity, resulting in an approximately 10% reduction in overall labor requirements and an approximately 30% decrease in operating costs.

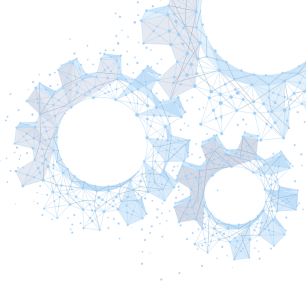
**Third, in terms of product quality:** The defect rate has decreased by approximately 30%, and the first-pass yield has improved by more than 20%.

**Fourth, in terms of inventory management:** Inventory accuracy has risen to over 98%, effectively supporting business decision-making.

**Fifth, in terms of green and safety performance:** Unit product energy consumption has been reduced by more than 30%, and the safety incident rate has decreased by 93.3%, providing strong assurance for continuous production.

The factory has adopted Double Star's proprietary MEP Intelligent Information Matching System, achieving intelligent information matching among materials, personnel, equipment, and locations. This has solved the industry-wide challenge of full-process automation for liquid and powder raw materials, increasing single-shift capacity by 150%.

In addition, the factory has developed a modular and efficient replication model for overseas intelligent factories. By adopting the implementation strategy of “informatization first, followed by intelligentization” and the self-developed “modular intelligent manufacturing system,” the factory has rapidly replicated domestic Smart Factory experience, established an information construction pathway suitable for overseas operations, and achieved the transformation from product export to “technology standard export.”.



## 德国——福耀汽车玻璃智能工厂

### 一、海外工厂整体情况

工厂坐落于德国巴登-符腾堡州莱茵加尔滕，成立于2007年10月，2018年底竣工投产。工厂总面积83,000平方米，拥有30余条生产线，包括15条全自动注塑生产线、13条全自动挡风玻璃装配生产线、3条全自动化后挡风玻璃涂底漆生产线，3条全自动侧窗底涂生产线等。工厂主营汽车玻璃及相关配件产品，主要为宝马、奥迪、大众、奔驰、兰博基尼、劳斯莱斯等知名汽车品牌提供定制化配套服务，产品涵盖挡风玻璃、全景天幕玻璃、智能调光玻璃等模块化产品。同时，依托“中国前道生产+欧洲增值加工”的协同模式，对中国出口的玻璃进行深加工，提升产品附加值与客户响应能力。

### 二、重点环节智能化建设情况

工厂以欧洲高端车企定制化需求为导向，形成了“数据贯通、AI质检、智能调度、柔性交付”的高端汽车玻璃智能制造模式。

#### 1. 研发设计：全球协同的智能研发

工厂深度融入福耀集团全域协同研发体系，依托集团打造的“全球协同+AI优化+数字孪生”一体化智能研发平台，打破地域协作限制，联动集团总部及各大研发中心合力开展研发工作。平台依托海量车型数据与深度学习算法搭建智能设计模型，精准适配海外车企标准与区域法规，针对AR-HUD玻璃、新能源轻量

化玻璃、隔热镀膜产品等优化各项性能与工艺参数，为跨区域联合研发提供强大技术支撑。

工厂全面接入福耀集团 PLM 产品全生命周期管理系统，实现中、欧、美多地研发主体数据互通，依托共建的本地化数字孪生库完成参数快速调用与方案适配，借助全工序虚拟仿真减少实物试制，有效压缩定制化研发周期。工厂立足当地市场做好需求对接与落地适配，充分共享集团技术资源与研发成果，以高效协同模式推进各类车载玻璃产品联合开发，持续提升整体研发效率与市场适配能力。

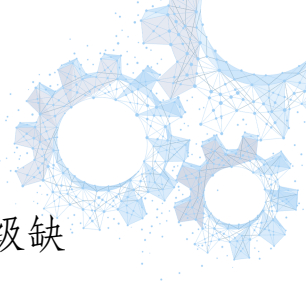
- AI智能设计项目通过参数化驱动和模块化库，实现模型快速生成与联动更新，大幅提升建模效率和一致性。相比传统人工重复建模，它支持版本关联迭代、标准件调用与自适应调整，显著减少重复工作，并形成标准化建模体系，助力团队能力提升。



图 1 AI 智能设计建模及变更

## 2. 生产制造：少人化、零缺陷、高柔性

工厂构建以 MES 系统为核心，联动工业互联网、机器人集群和 AI 视觉检测的智能化生产体系，实现从原料加工到成品出库的全流程自动化管控。依托 AI 智能调度系统实时采集订单优先级、设备状态、物料齐套性等数据，动态调整生产节拍与工序衔接，最快 2 小时完成车型规格切换，支持多品种、小批量混线



生产。关键工序部署 2000 万像素 AI 视觉设备，对 0.01mm 级缺陷进行 100%全检，检测效率较人工提升 50 倍，漏检率控制在 0.01%以下。产品全域溯源体系完善，每片玻璃绑定唯一数字 ID，数据实时上传 MES 系统，形成“原料—加工—质检—成品”全生命周期追溯链。工业物联网传感器结合 AI 预测性维护模型，提前预警设备故障风险，非计划停机时间减少 30%，设备综合效率（OEE）提升至 85%以上，同步搭建车间级数字孪生平台，实时映射产线状态，实现生产透明化管控。

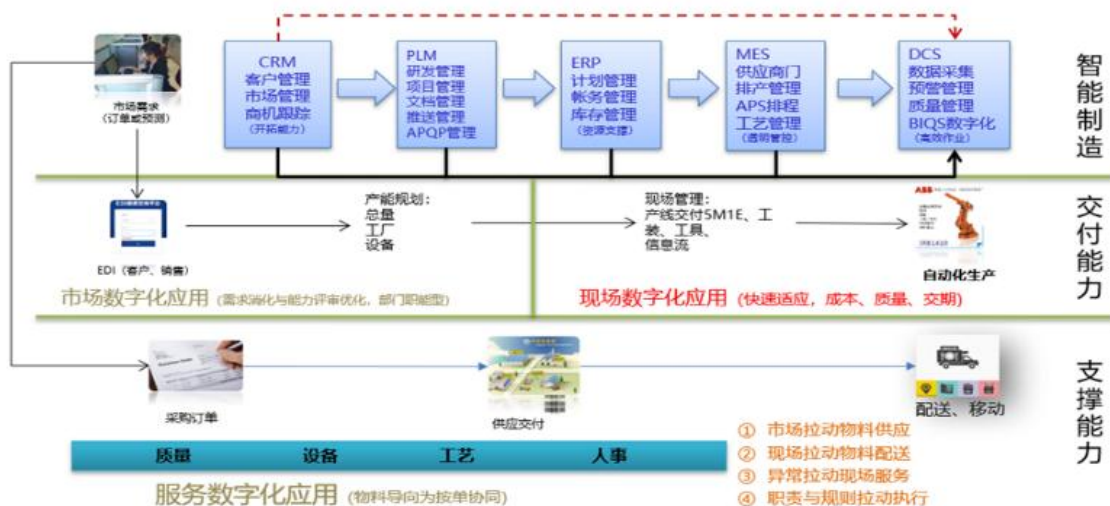


图 2 工厂数字化应用架构

### 3. 运营管理：从订单到交付的全链路智能决策

工厂构建“ERP-MES-SRM”一体化数字管理平台，以 AI 算法推动运营管理由经验驱动向数据驱动转变。整合车企生产计划、历史订单、市场趋势及外部因素搭建需求预测模型，科学指导采购计划与库存配置。动态优化运输路线、装载方案与报关流程，并联动全球物流伙伴实现数据互通。借助 MES 系统整合设备负荷、人员班次、交期要求等数据，自动生成并动态调整生产计划。

搭建质量大数据平台，联动生产参数、设备状态、原料批次等信息，精准完成质量问题根源分析。依托运营驾驶舱实时呈现产能、良率、能耗等核心经营指标，基于 AI 实现异常自动监控并预警，辅以智能知识库与虚拟培训系统，全面提升组织运行效率。

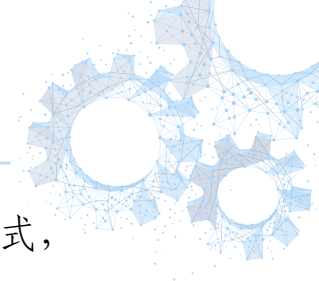
系统模型与动态实时数据，支撑交付异常快速反应处理



图 3 MES 动态计划排产系统

### 三、工厂实施成效与特色亮点

工厂通过全链条智能化升级，实现成效成果与体系建设双向赋能。一是质量和效率等方面显著提升，研发周期缩短 30%，一次开发成功率提高 40%，产品良率由 98% 提升至 99.98%，质检漏检率控制在 0.01% 以下，生产效率提升 25%，订单交付达成率达 95%，库存周转率提升 20%，缺货率降至 1% 以下，机器人密度达 500 台/万人，单位产品能耗降低 8%，物料损耗率下降 30%。二是构建以“AI+数字技术+先进制造”为核心的全链条智能化体系，依托 PLM 系统实现中欧美十大研发中心实时协同，结合欧洲本地化数字孪生库，高效适配高端车型定制化需求，AI 深度融入参数寻优、质量检测、需求预测等关键环节，形成“数据—算法



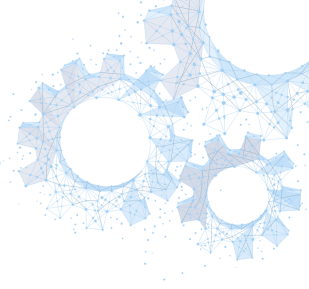
—决策”闭环，成功打造制造业出海智能化转型的可复制模式，  
树立“中国智造”海外落地的技术标杆。

## **Germany—Fuyao Automotive Glass Smart Factory**

### **I. Overview of the Overseas Factory**

The factory is located in Reilingen, Baden-Württemberg, Germany. It was established in October 2007 and completed construction and commenced production at the end of 2018. Covering a total area of 83,000 square meters, the factory is equipped with more than 30 production lines, including 15 fully automated injection molding lines, 13 fully automated windshield assembly lines, 3 fully automated rear windshield primer coating lines, and 3 fully automated side window primer coating lines.

The factory specializes in automotive glass and related accessory products, primarily providing customized supporting services for renowned automotive brands such as BMW, Audi, Volkswagen, Mercedes-Benz, Lamborghini, and Rolls-Royce. Its product portfolio covers modular solutions including windshields, panoramic sunroof glass, and intelligent dimming glass. At the same time, leveraging the synergistic model of “upstream production in China + value-added processing in Europe,” the factory performs deep processing on glass exported from China, thereby enhancing product added value and customer response capabilities..



## **II. Status of Intelligent Construction in Key Areas**

The factory is oriented toward the customized demands of European premium automotive OEMs and has developed a high-end automotive glass intelligent manufacturing model featuring “full data connectivity, AI quality inspection, intelligent scheduling, and flexible delivery.”

### **1. R&D and Design: Global Collaborative Intelligent R&D**

The factory is deeply integrated into Fuyao Group’s full-domain collaborative R&D system. Leveraging the Group’s integrated intelligent R&D platform of “global collaboration + AI optimization + digital twin,” it breaks down geographical collaboration barriers and coordinates efforts with the Group headquarters and major R&D centers to jointly carry out R&D activities.

The platform constructs intelligent design models based on massive vehicle model data and deep learning algorithms, precisely adapting to overseas OEM standards and regional regulations. It optimizes performance and process parameters for products such as AR-HUD glass, new energy lightweight glass, and heat-insulating coated products, providing strong technical support for cross-regional joint R&D.

The factory has full access to Fuyao Group’s PLM product lifecycle management system, enabling seamless data interoperability among R&D entities in China, Europe, and the United States. Relying on the jointly established localized digital twin database, it achieves rapid parameter retrieval and solution adaptation. Through full-process virtual simulation, it reduces physical prototyping, effectively shortening the customized R&D cycle. The factory focuses on local market demand alignment and adaptation while fully sharing the Group’s technical resources and R&D achievements. This highly efficient collaborative model advances the joint development of various automotive glass products, continuously improving overall R&D efficiency and market adaptability.

- **AI-driven intelligent design:** Through parameter-driven modeling and a modular library, the project enables rapid model generation and synchronized updates, significantly improving modeling efficiency and consistency. Compared with traditional repetitive manual modeling, it supports version-linked iteration, standard component reuse, and adaptive adjustment, greatly reducing repetitive work. It also helps establish a standardized modeling system and strengthens the team’s overall capabilities.

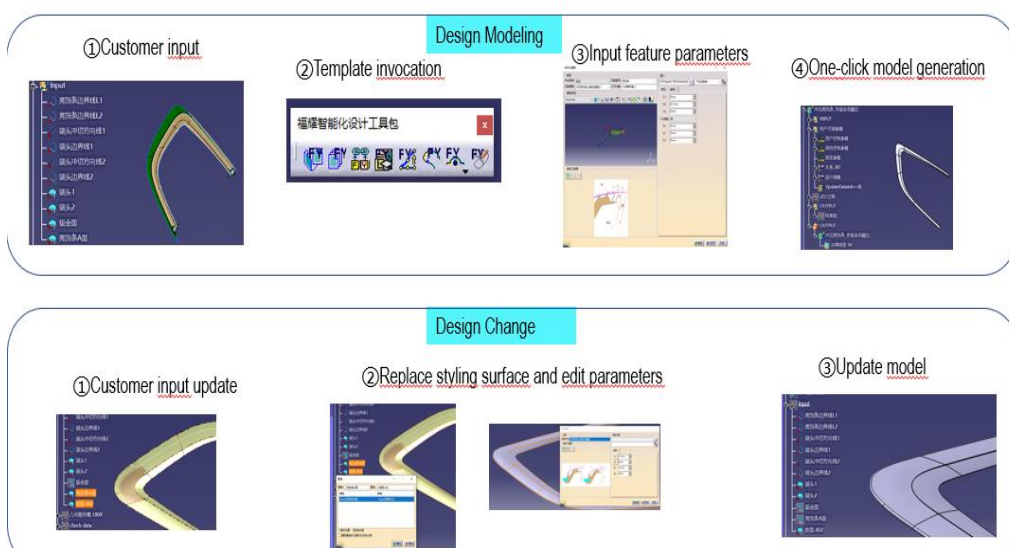


Figure 1: AI Intelligent Design Modeling and Change Management



## **2. Production and Manufacturing: Labor Reduction, Zero Defects, and High Flexibility**

The factory has established an intelligent production system centered on the MES system and integrated with the Industrial Internet, robot clusters, and AI vision inspection. This system achieves full-process automated control from raw material processing to finished product outbound.

Leveraging the AI intelligent scheduling system, the factory collects real-time data on order priority, equipment status, and material completeness, dynamically adjusting production takt time and process connections. It can complete model and specification changeovers in as little as two hours, supporting multi-variety, small-batch mixed-line production.

In critical processes, 20-megapixel AI vision equipment has been deployed to perform 100% full inspection of defects at the 0.01 mm level. Inspection efficiency is 50 times higher than manual inspection, with the missed detection rate controlled below 0.01%.

The factory has established a comprehensive product traceability system. Each piece of glass is assigned a unique digital ID, with data uploaded to the MES system in real time, forming a full-lifecycle

traceability chain from “raw material—processing—quality inspection—finished product.”

Industrial IoT sensors combined with AI predictive maintenance models provide early warnings of equipment failure risks. Unplanned downtime has been reduced by 30%, overall equipment effectiveness (OEE) has increased to over 85%, and a workshop-level digital twin platform has been built simultaneously. This platform maps the production line status in real time, achieving transparent production management..

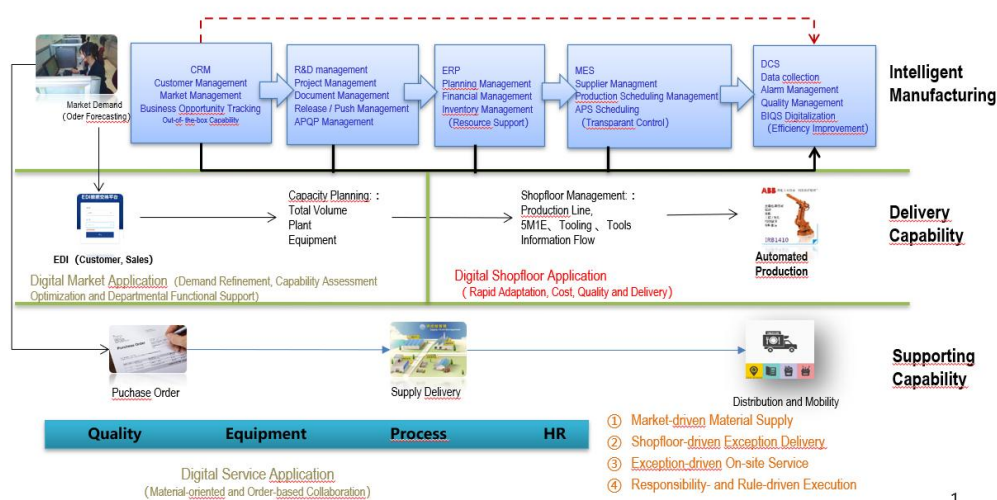


Figure 2: Factory Digital Application Architecture

### 3. Operations Management: Full-Chain Intelligent Decision-Making from Order to Delivery

The factory has built an integrated digital management platform of “ERP-MES-SRM,” using AI algorithms to drive the transformation of



operations management from experience-based to data-driven decision-making. By integrating OEM production plans, historical orders, market trends, and external factors, a demand forecasting model has been established to scientifically guide procurement planning and inventory allocation. Transportation routes, loading schemes, and customs clearance processes are dynamically optimized, while data interoperability is realized with global logistics partners.

Leveraging the MES system, data on equipment load, personnel shifts, and delivery requirements are integrated to automatically generate and dynamically adjust production plans. A quality big data platform has been established to link production parameters, equipment status, and raw material batches, enabling precise root-cause analysis of quality issues. An operations cockpit provides real-time visualization of core business indicators such as capacity, yield, and energy consumption. AI enables automatic monitoring and early warning of anomalies, supported by an intelligent knowledge base and virtual training system, comprehensively improving organizational operational efficiency.

System Model and Dynamic Real-Time Data Support Rapid Response to Delivery Exceptions

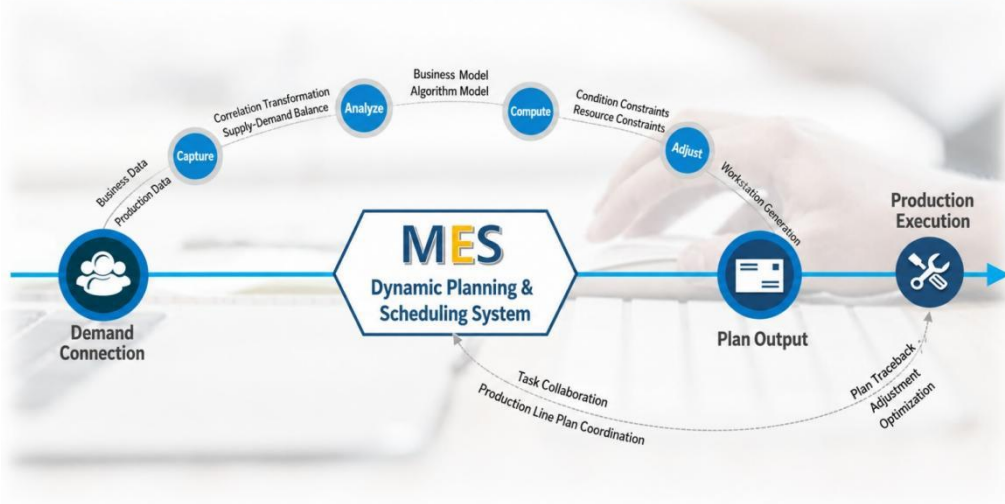
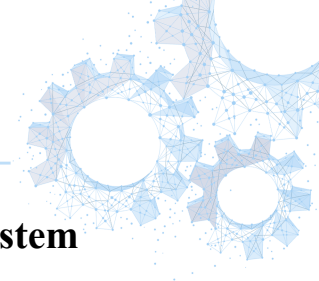


Figure 3: MES Dynamic Production Scheduling System

### III. Implementation Effectiveness of the Overseas Factory

The factory has achieved bidirectional empowerment between performance outcomes and system construction through full-chain intelligent upgrading.

**First, significant improvements have been realized in quality and efficiency.** The R&D cycle has been shortened by 30%, the first-time development success rate has increased by 40%, the product yield rate has risen from 98% to 99.98%, the quality inspection missed detection rate has been controlled below 0.01%, production efficiency has increased by 25%, the order delivery fulfillment rate has reached 95%, the inventory turnover rate has improved by 20%, the stockout rate has been reduced to below 1%, robot density has reached 500 units per 10,000 employees, unit product energy consumption has decreased by 8%, and the material loss rate has declined by 30%.



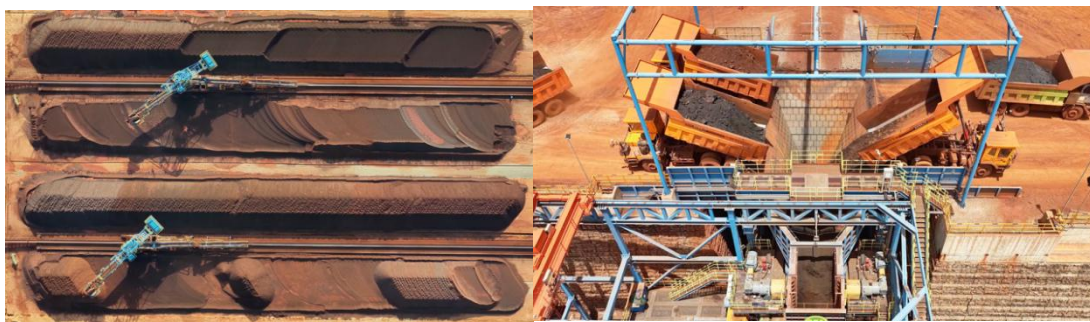
**Second, the factory has built a full-chain intelligent system centered on “AI + digital technology + advanced manufacturing.”**

Relying on the PLM system, it enables real-time collaboration among ten R&D centers across China, Europe, and the United States. Combined with the localized European digital twin database, it efficiently adapts to the customized needs of premium vehicle models. AI is deeply integrated into key processes such as parameter optimization, quality inspection, and demand forecasting, forming a closed loop of “data—algorithm—decision-making.” This has successfully created a replicable model for the intelligent transformation of manufacturing enterprises going overseas and established a technical benchmark for the overseas implementation of “Chinese Intelligent Manufacturing.”

## 几内亚——宝武超大型采矿智能工厂

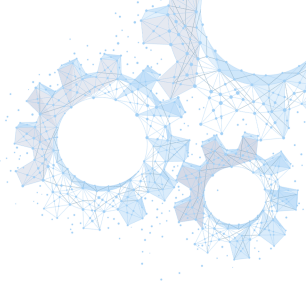
### 一、海外工厂整体情况

工厂（西芒杜 BWCS 矿山）坐落于几内亚东南部，是**世界级超大型优质露天赤铁矿**。项目由中国宝武钢铁集团有限公司下属宝武资源有限公司控股 51%，与赢联盟合作开发运营，是宝武资源践行国家资源安全保障战略、在海外打造的全球级智能矿山标杆。矿山建设克服偏远荒芜、无基础设施依托等极端条件，**从零构建全链条穿透式智能矿山**。矿山主要产品为高品位铁矿石，设计采选总规模达 6000 万吨/年，总投资超百亿元。宝武资源有限公司通过该矿山为全球钢铁企业提供稳定、优质的低碳原料，综合竞争力处于行业前列。



### 二、重点环节智能化建设情况

工厂以本质安全、极致效率、绿色低碳、智能决策为目标，构建起“智慧运营 - 智能管控 - 智能作业 - 基础设施”四层穿透式智能矿山体系，实现“感知 - 执行 - 管控 - 决策”端到端闭环贯通，全域数据实时穿透、全流程业务无缝协同，彻底打破传统矿山“信息孤岛”与“断点管理”，形成了超大型海外智能矿山的鲜明



特色。

### 1. 智能工厂总体架构

工厂采用四层协同架构，从数字底座到智能作业、一体化管控再到智慧运营，层层支撑、逐级赋能：在底座层（基础设施），打造“融合通信+边缘计算+工业互联网”数字化底座，自建4G/LTE企业专网，实现全域数据统一治理与共享；在执行层（智能作业），聚焦采矿、选矿、重油发电及公辅设施，完成生产全流程自动化改造与智能化控制，夯实少人化、无人化基础；在中枢层（智能管控），建设一体化生产管控平台（MMS），实现生产、设备、物资、能源核心要素的实时监控、精益管控与动态优化；在战略层（智慧运营），与集团境内外一体化智慧治理及供应链协同平台无缝对接，实现对超大型海外矿山从生产到运营、从境内到海外的全链条穿透式管理与协同。



图 1 西芒杜 BWCS 智能矿山总体架构图

### 2. 研发设计：从资源评估到采矿设计全链条数据贯通

通过地测采系统与统一协同平台构建，实现从地质勘探到生产作业的端到端数据流转，形成“评估—建模—设计—优化”的闭环

环体系。数据贯通将静态资源数据转化为动态作业指令，确保开采全过程的可视、可算与资源利用最大化。一是资源数字化，依托数字化勘探与资源评估体系，将地质勘探、炮孔采样、物探遥感等数据统一归集至数据协同平台，实时更新、动态核算，精准圈定矿体边界、估算资源量、划分品级，为采矿设计、配矿调度、质量管控提供唯一数据源头。二是实现三维地质建模，利用数字化软件构建矿体、地表、工程三维实体模型与资源块体模型，支持PC端与移动端协同操作，实现矿体品位动态估算，形成价值模型、采矿模型、品位控制模型。结合智能优化算法自动编制中长期/短期采矿计划与配矿方案，数据直接下发至卡车调度系统与生产管控平台。三是采矿智能化设计，采矿生产技术协同平台实现地质模型、采矿设计、爆破设计各环节数据端到端贯通，设计方案无缝转化为施工计划与作业指令，确保“设计-工艺-管控-作业”全流程可视、可算、可仿、可控。



图2 西芒杜BWCS智能矿山数字孪生平台

### 3. 生产制造：从采场到装车全流程穿透

通过智能调度、自动化产线与全过程质量反馈的深度耦合，构建起从“资源采掘”到“成品装车”的数字化穿透链条。全流程穿透实现电力、设备与工艺的联动，确保生产的**自动化运行、精细化配矿与质量稳定达标**。一是**构建采矿卡车调度系统**。系统接入200台电动矿卡、30台采掘设备及120台辅助车辆，与地测采三维平台深度联动，自动接收配矿计划与品位指标，通过自主优化算法动态调度车辆路径，实时监测破碎站入料品位，实现夹石智能识别与全链条质量控制，确保品位稳定。二是**应用选矿智能装备**。全套大型化、智能化装备覆盖破碎、筛分、输送、布料、堆取、装车全工艺，统一接入DCS系统。构建“中央集控+分布式控制”架构，关键参数根据上游在线检测结果自动调节，下游成品质量数据反向反馈至采场配矿，实现选矿全链条无人值守、闭环优化。三是**实现电力自动化**。构建源网荷储一体化微电网系统，实现重油发电机组、供配电线路、选矿产线用电设备、分布式储能系统的远程集中监控与智能调度，保障全链条生产连续稳定。四是**推进全流程质量控制**。在破碎、筛分、输送、装车等关键节点部署在线品位、水分、块度分析仪，数据毫秒级上传中央管控平台，地测采平台生成动态配矿方案，卡车调度精准执行，选矿产线自动调控，成品堆场4D智能料场均质化取料，确保 $TFe\geq 65\%$ 稳定达标。



图3 西芒杜 BWCS 智能矿山智能卡调系统

#### 4. 运营管理：从生产执行到经营决策全链条贯通

依托数据协同平台打通云、边、端架构，将 MMS 管控、设备运维与资源管理深度融合，构建起“全域覆盖、实时联动”的智能化运营体系，消除生产执行与经营决策间的壁垒，实现从底层万个点位感知到顶层精益管理的端到端数据穿透。一是实现生产管控一体化。MMS 生产管控平台贯穿采矿、选矿、公辅全流程，融合十大专业系统，实现生产计划、过程管控、质量、设备、能源、物流全要素动态跟踪与智能优化，全域数据实时汇聚分析，形成生产全链条动态闭环。二是推进设备智能运维、能源智能管理、物资高效管控。设备全生命周期台账、能源计量体系、物资全流程管理系统全部接入数据协同平台，实现预测性维护、能耗优化、库存预警与生产计划、质量控制的端到端联动。三是完成数据协同全域贯通。数据协同平台以边缘计算为核心，接入十大业务系统、超 180 套核心设备、1.6 万余数据点位，完成多源异构数据采集、治理、共享全链路贯通，人工统计工作量减少 85%，为全链条穿透提供统一数据底座。

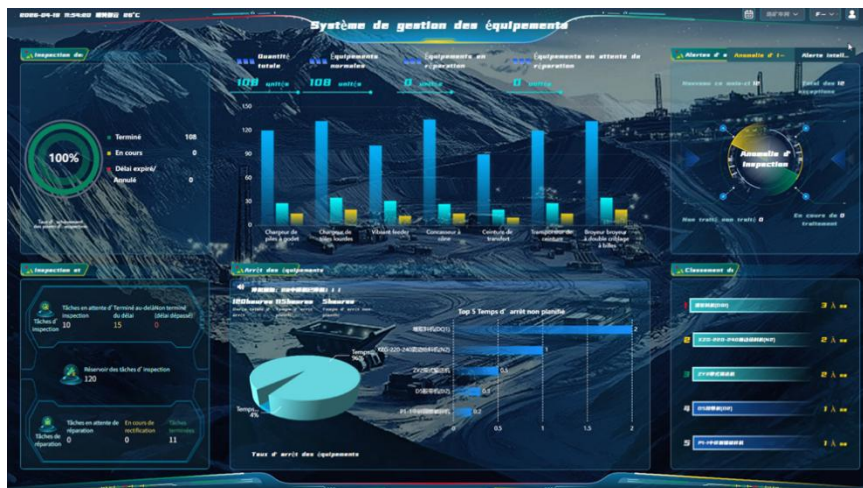


图4 西芒杜 BWCS 智能矿山设备管理系统

### 三、工厂实施成效

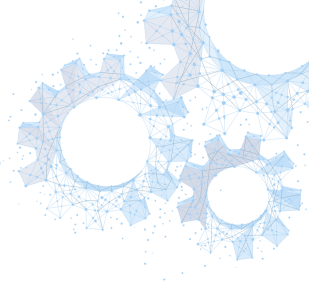
在实施成效方面，工厂一系列 3000 万吨/年于 2025 年 11 月投产，二系列 3000 万吨/年计划 2026 年下半年建成投产，目前处于产能爬坡期。一是**核心运营指标表现卓越**，输出的铁矿石质量合格率保持 100%， $TFe \geq 65\%$  稳定达标，矿山人员配置精简，全员劳动生产率行业领先，吨矿运营成本远低于行业平均水平。二是**打造全链条穿透式智能矿山标杆**，在偏远荒芜、无基础设施的地区从零建成，实现地质建模、生产计划、智能配矿、设备运维、质量管控、能源管理等全业务协同，为全球矿业数字化转型贡献了宝贵的“中国智慧”与“宝武方案”。三是**实现全流程少人化和绿色低碳协同**。选矿、堆存、装车、巡检、公辅全环节少人/无人化，大幅降低现场作业风险，配置大型智能化绿色装备，投入电动矿卡降低碳排放，采用智能负荷优化控制显著降低能耗，形成“高产、低耗、环保、稳定”的超大型海外智能矿山运营模式。

# Guinea—Baowu Ultra-large Mining Smart Factory

## I. Overview of the Overseas Factory

The project (Simandou BWCS Mine) is located in southeastern Guinea and represents a world-class ultra-large high-quality open-pit hematite mine. The project is 51% controlled by Baowu Resources Co., Ltd., a subsidiary of China Baowu Steel Group Co., Ltd., and is developed and operated in partnership with the Winning Consortium. It serves as a global-class intelligent mining benchmark established by Baowu Resources to implement the national resource security strategy.

Overcoming extreme conditions such as extreme remoteness, barren terrain, and complete lack of supporting infrastructure, the mine has been built from scratch as a full-chain, end-to-end intelligent mining operation. Its primary product is high-grade iron ore, with a designed total mining and beneficiation capacity of 60 million tons per year and a total investment exceeding RMB 10 billion. Through this mine, Baowu Resources Co., Ltd. supplies stable, high-quality, low-carbon raw materials to global steel enterprises, maintaining overall competitiveness at the forefront of the industry.



## **II. Status of Intelligent Construction in Key Areas**

The mine is guided by the goals of intrinsic safety, ultimate efficiency, green and low-carbon development, and intelligent decision-making. It has established a four-layer end-to-end intelligent mining system of “Intelligent Operations – Intelligent Control – Intelligent Execution – Infrastructure,” achieving full end-to-end closed-loop connectivity across “Perception – Execution – Control – Decision-Making.” This enables real-time data penetration across the entire domain and seamless collaboration throughout all business processes, completely breaking down traditional “information silos” and “breakpoint management” in mining operations and forming the distinctive characteristics of an ultra-large overseas intelligent mine..

### **1. Overall Architecture of the Smart Factory**

The mine adopts a four-layer collaborative architecture, with each layer supporting and empowering the next—from the digital foundation to intelligent execution, integrated control, and ultimately intelligent operations:

At the foundation layer (Infrastructure), a digital base integrating “converged communications + edge computing + Industrial Internet” has been established. A self-built 4G/LTE private enterprise network

has been deployed to enable unified governance and sharing of data across the entire site.

At the execution layer (Intelligent Execution), the focus is on mining, beneficiation, heavy-oil power generation, and auxiliary facilities. Full-process automation transformation and intelligent control have been completed, laying a solid foundation for labor reduction and unmanned operations.

At the central control layer (Intelligent Control), an integrated production management and control platform (MMS) has been built to achieve real-time monitoring, lean management, and dynamic optimization of core elements including production, equipment, materials, and energy.

At the strategic layer (Intelligent Operations), seamless integration has been realized with the Group's integrated intelligent governance and supply chain collaboration platform across domestic and overseas operations, enabling full-chain, end-to-end management and collaboration for this ultra-large overseas mine—from production to operations and from domestic to overseas sites.

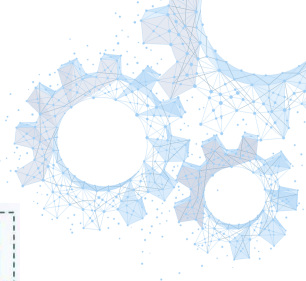


Figure 1: Overall Architecture Diagram of the Simandou BWCS Intelligent Mine

## 2. R&D and Design: Full-Chain Data Connectivity from Resource Assessment to Mining Design

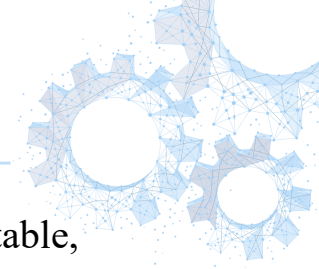
Through the integration of the geological surveying and mining system with a unified collaboration platform, end-to-end data flow from geological exploration to production operations has been realized, forming a closed-loop system of “assessment—modeling—design—optimization.” This full-chain data connectivity transforms static resource data into dynamic operational instructions, ensuring visualization, computability, and maximum resource utilization throughout the entire mining process.

First, resource digitization. Relying on a digital exploration and resource assessment system, data from geological exploration, blast-hole sampling, geophysical remote sensing, and other sources are

centrally collected into the data collaboration platform for real-time updates and dynamic accounting. This enables precise delineation of orebody boundaries, accurate estimation of resource volumes, and grade classification, providing a single source of truth for mining design, ore blending and scheduling, and quality control.

Second, three-dimensional geological modeling. Digital software is used to construct three-dimensional solid models of the orebody, surface, and engineering structures, as well as resource block models. These support collaborative operations on both PC and mobile terminals, enabling dynamic grade estimation and the creation of value models, mining models, and grade control models. Combined with intelligent optimization algorithms, medium- and long-term as well as short-term mining plans and ore-blending schemes are automatically generated and directly issued to the truck dispatching system and production control platform.

Third, intelligent mining design. The mining production technology collaboration platform achieves end-to-end data connectivity across geological modeling, mining design, and blasting design. Design schemes are seamlessly converted into construction plans and operational instructions, ensuring that the entire process of “design—



process—control—execution” is visualized, computable, simulatable, and controllable.



Figure 2: Digital Twin Platform of the Simandou BWCS Intelligent Mine

### 3. Production and Manufacturing: Full-Process Penetration from Stope to Truck Loading

Through the deep coupling of intelligent dispatching, automated production lines, and full-process quality feedback, the mine has built a digitized penetration chain from “resource extraction” to “finished product loading.” This full-process penetration enables linkage among power, equipment, and processes, ensuring automated operation, refined ore blending, and stable quality compliance.

**First, a mining truck dispatching system has been established.** The system integrates 200 electric mining trucks, 30 excavation units, and 120 auxiliary vehicles, deeply linked with the geological surveying

and mining 3D platform. It automatically receives ore-blending plans and grade targets, dynamically optimizes vehicle routes through autonomous algorithms, and monitors feed grade at the crushing station in real time. Intelligent identification of waste rock and full-chain quality control are realized, ensuring stable ore grade.

**Second, intelligent beneficiation equipment has been deployed.** A complete set of large-scale, intelligent equipment covers the full process of crushing, screening, conveying, distribution, stacking/reclaiming, and loading, all uniformly connected to the DCS system. A “centralized control + distributed control” architecture has been built, with key parameters automatically adjusted according to upstream online detection results and downstream finished product quality data fed back to the stope for ore blending. This achieves unmanned, closed-loop optimization across the entire beneficiation chain.

**Third, power automation has been implemented.** An integrated source-grid-load-storage microgrid system has been constructed for remote centralized monitoring and intelligent dispatching of heavy-oil generator sets, power distribution lines, beneficiation production line equipment, and distributed energy storage systems, ensuring continuous and stable production across the full chain.



**Fourth, full-process quality control has been advanced.** Online grade, moisture, and lump size analyzers have been deployed at critical nodes such as crushing, screening, conveying, and loading. Data is uploaded to the central control platform in milliseconds. The geological surveying and mining platform generates dynamic ore-blending schemes, which are precisely executed by the truck dispatching system. The beneficiation line automatically regulates parameters, while the finished product stockyard employs 4D intelligent homogenization and reclaiming, ensuring stable compliance with  $TFe \geq 65\%$ ..



Figure 3: Intelligent Truck Dispatching System of the Simandou BWCS Intelligent Mine

#### 4. Operations Management: Full-Chain Connectivity from Production Execution to Business Decision-Making

Relying on the data collaboration platform to connect the cloud-edge-end architecture, the mine deeply integrates MMS control, equipment

operation and maintenance, and resource management. This has built an intelligent operations system characterized by “full-domain coverage and real-time linkage,” eliminating barriers between production execution and business decision-making, and achieving end-to-end data penetration from perception at tens of thousands of bottom-level points to top-level lean management.

First, integrated production control has been realized. The MMS production management and control platform spans the entire process of mining, beneficiation, and auxiliary facilities, integrating ten major professional systems. It enables dynamic tracking and intelligent optimization of all elements—including production planning, process control, quality, equipment, energy, and logistics—with real-time aggregation and analysis of full-domain data, forming a dynamic closed loop across the entire production chain.

Second, intelligent equipment operation and maintenance, intelligent energy management, and efficient material control have been advanced. The full-lifecycle equipment ledger, energy metering system, and full-process material management system are all connected to the data collaboration platform, realizing end-to-end linkage among predictive maintenance, energy consumption



optimization, inventory early warning, production planning, and quality control.

Third, full-domain data collaboration has been completed. With edge computing at its core, the data collaboration platform connects ten major business systems, more than 180 sets of core equipment, and over 16,000 data points. It achieves full-chain connectivity for multi-source heterogeneous data collection, governance, and sharing, reducing manual statistical workload by 85% and providing a unified data foundation for full-chain penetration.

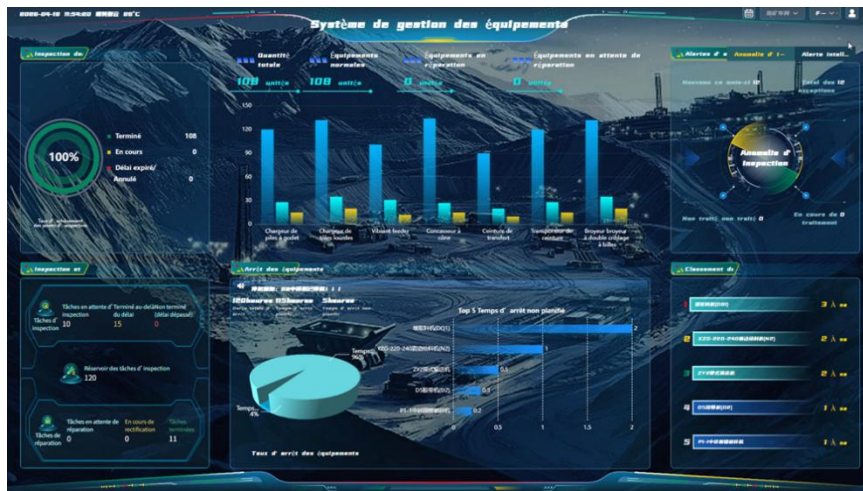


Figure 4: Equipment Management System of the Simandou BWCS Intelligent Mine

### III. Implementation Effectiveness of the Overseas Factory

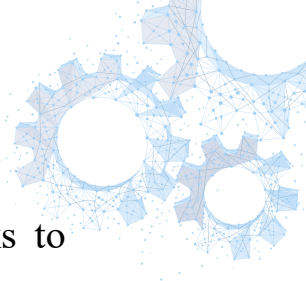
In terms of implementation effectiveness, the first series of the 30-million-ton-per-year project commenced production in November 2025, while the second series of the 30-million-ton-per-year project is

scheduled for completion and commissioning in the second half of 2026. The mine is currently in the capacity ramp-up phase.

First, core operational indicators have demonstrated outstanding performance. The quality compliance rate of the iron ore produced has remained at 100%, with TFe  $\geq$  65% stably achieved. The mine maintains a lean staffing structure, with per-employee labor productivity leading the industry and per-ton operating costs significantly below the industry average.

Second, the mine has established a benchmark for full-chain end-to-end intelligent mining operations. Built from scratch in a remote, barren area with no existing infrastructure, it has achieved comprehensive business collaboration across geological modeling, production planning, intelligent ore blending, equipment operation and maintenance, quality control, and energy management. This has contributed valuable “Chinese wisdom” and the “Baowu Solution” to the global mining industry’s digital transformation.

Third, full-process labor reduction and green low-carbon synergy have been realized. Unmanned or minimally manned operations have been implemented across all links, including beneficiation, stockpiling, loading, inspection, and auxiliary facilities, significantly reducing on-site operational risks. Large-scale intelligent green



equipment has been deployed, including electric mining trucks to reduce carbon emissions, while intelligent load optimization control has markedly lowered energy consumption. This has formed a highly productive, low-consumption, environmentally friendly, and stable operational model for an ultra-large overseas intelligent mine.

## 印度尼西亚——三一挖掘机智能工厂

### 一、海外工厂整体情况

PT SANY INDONESIA MACHINERY（三一挖掘机智能工厂）位于印度尼西亚卡拉旺 KIM 工业园，是三一集团全球化主战略的核心标杆，也是中国工程机械行业首个完全依照工业 4.0 标准规划建设海外智能制造基地。工厂于 2022 年建成并实现首台挖掘机下线，2023 年启动二期扩建，2024 年 7 月二期项目顺利投产，工厂占地面积约 10 万平方米，具备年产 3 吨至 55 吨全系列挖掘机 6000 台的产能。产品不仅满足印尼本土市场需求，更远销英国、美国等全球主流市场，成为三一推动高端制造能力、供应链体系和品牌价值系统化出海的关键战略支点。

### 二、重点环节智能化建设情况

工厂以“极致柔性、数据驱动、全球协同”为核心特征，深度融合数字孪生、柔性自动化、物联网及智能运营管理等技术，构建起先进的制造平台，能够快速响应全球市场变化，支撑多机型高效共线生产。

## 1. 智能工厂总体架构

工厂以“数据驱动、系统贯通、合规本地、全球协同”为核心理念，重构数字底座，高质量完成涵盖四大转型域、八项核心系统、六大类关键设备、两级管控、五大业务闭环的数字化转型任务。以自主研发的 iMOM 为核心，深度集成 SAP、WMS、CRM、MDM 等系统，并成功打通印尼本地 KPPBC、SINDU、E-Nofa、CEISA 等关键合规系统，构建统一的业务平台。在此基础上，显化固化了 32 支本地化流程、78 项核心业务流程，搭建统一流程门户，使得运营效率提升 25% 以上，实现端到端业务闭环与组织协同高效升级。

## 2. 研发设计：国内外端到端协同研发

工厂在建设前期全面应用数字化仿真技术，践行“先模拟、后建设”的理念。一是数字孪生工厂建模，在虚拟空间中构建了涵盖厂房、生产线、物流的全要素三维数字孪生模型，对整体布局及人流、物流进行仿真优化，确保物理工厂设计达到最优。二是工艺仿真验证，针对复杂装配工艺，在虚拟环境中对装配序列、机器人工作路径、工时平衡等进行模拟与调试，提前发现并解决潜在问题，将工艺验证与优化前置，大幅缩短后期现场调试周期，确保工艺方案的先进性与可靠性。

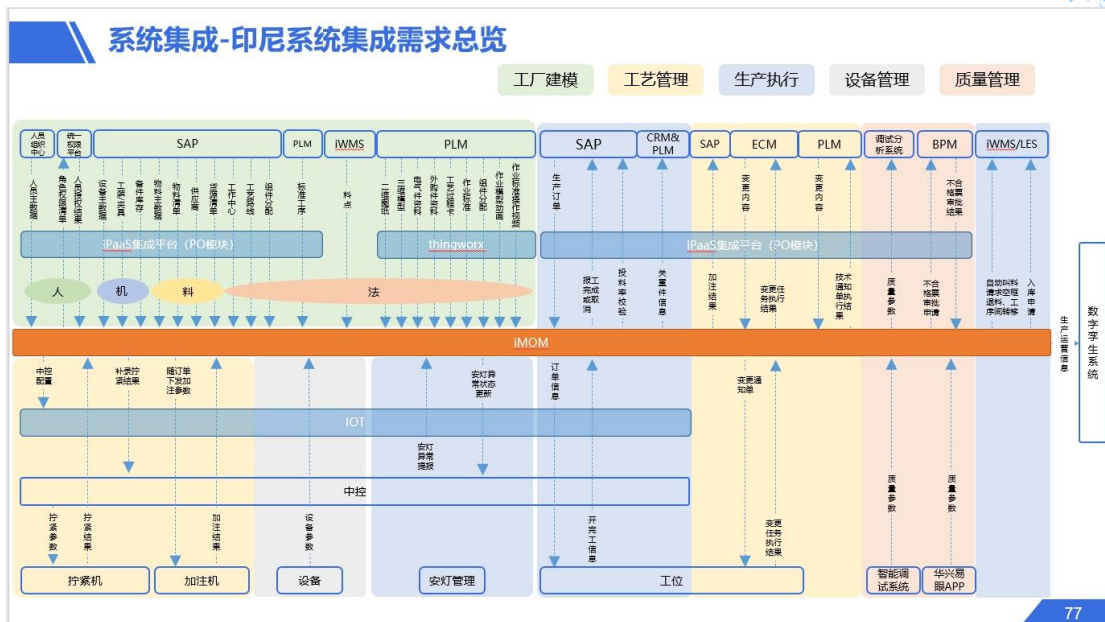


图 1 三一印尼系统集成图

### 3. 生产制造：柔性共线智能生产

生产线采用高度柔性化和智能化设计，以应对多品种、小批量的全球化生产需求。一是智能装备与自动化产线集成，产线集成了自动翻转机、自动加注设备、自动铺履带系统、自动拧紧装置等系列自动化设备，通过标准化接口和可编程逻辑，可适配不同机型及配置的作业要求，实现关键装配工序的自动化操作与精度保障。二是智能化系统应用，应用 UWB 高精度定位技术，为在制品和物料配备定位标签，实现生产进度的自动实时报工与全程透明追踪；AGV 系统根据 iMOM 指令，实现物料从仓库到生产线边工位的自动、准时配送；中控系统打通所有自动化设备底层通信协议，实现设备互联与集中监控。

◆ 承接数字孪生看板成果，提供基础数据，实现如下数字孪生看板在印尼的运用

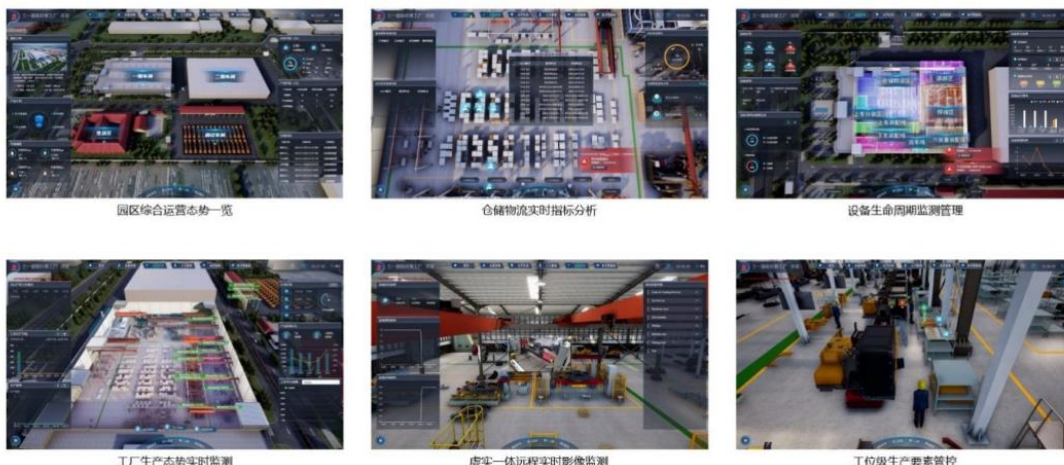
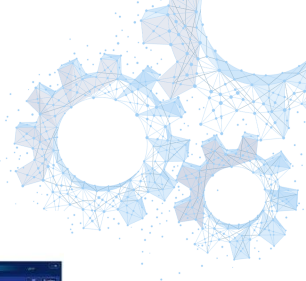


图 2 生产作业环节

### 4. 运营管理：数据驱动的一体化智能调度体系

通过信息系统的高度集成与数据的实时流动，构建了智能决策与调度中心。一是智能运营管理中枢，以自主研发的 iMOM(智能制造运营管理系统)为智慧大脑，向上对接 SAP 获取订单与物料信息，向下集成 WMS 与自动化设备，实现从工艺设计、智能派工、生产执行、过程自检到成品入库的全环节集中管理与智能调度。二是智能仓储管理，WMS 系统对仓库进行精细化管理，实现物料的智能入库、存储、拣选与出库，并与 AGV 系统、生产线需求实时联动，确保物料供应的高效与准确，实现仓储作业与物料配送的全面在线管理与精准可视化监控。



◆ 现场已打通关键数据，实现如下主要看板，以展示业务关键数据：

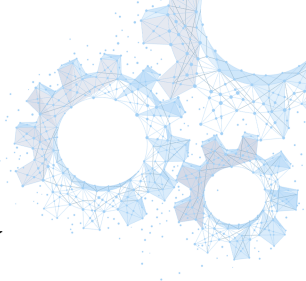


图 3 智能制造运营管理系统

### 三、工厂实施成效

工厂总投资 2 亿元，应用了 20 套拥有 100%自主知识产权的数字化软件系统，通过近千个数据采集点，与国内 3000 多公里外的三一全球生产管控中心实时数据互联，实现了效率、柔性、质量、成本的全方位升级。在效率方面，2022 年 7 月启动首批设备安装调试，仅用 30 天便实现首台挖掘机下线，创造了行业罕见的建设速度。工厂共部署 500 多台各类机器人，规划人均产值高达 1100 万元，是中国工程机械当前智能化程度最高、人均产值最高的海外工厂之一。在柔性方面，面对 2025 年美国关税和英国“双反”贸易政策，工厂未进行产线大规模改造，仅用八个月便成功导入面向欧美市场的十余款新机型并实现共线生产。投产三年来，累计生产超 2000 台设备，产品成功辐射欧美高端市场。在质量方面，关键工序自动化从根本上减少了人为操作差异，产品一次合格率显著提升。在成本方面，通过 AGV 精准配送、UWB 实时追踪、WMS 与 iMOM 系统集成，实现物料精准配送

与生产进度实时透明，显著降低运营与物流成本。该工厂的建设标志着我国工程机械行业从“产品出海”迈入“智能制造体系出海”的新阶段。



## Indonesia—Sany Excavator Smart Factory

### I. Overview of the Overseas Factory

PT SANY INDONESIA MACHINERY (SANY Intelligent Excavator Factory), located in the KIM Industrial Park in Karawang, Indonesia, serves as a core benchmark of SANY Group's globalization strategy and represents the first overseas intelligent manufacturing base in China's construction machinery industry to be fully planned and constructed in accordance with Industry 4.0 standards. The factory was completed in 2022, with the first excavator rolling off the assembly line. Phase II expansion commenced in 2023, and in July 2024, the Phase II project was successfully put into operation. Covering an area of approximately 100,000 square meters, the factory has an annual production capacity of 6,000 units of its full range of excavators, from 3 to 55 tons. Its products not only meet the demands of the Indonesian local market but are also exported to major global markets such as the United Kingdom and the United States, establishing the factory as a key strategic pivot for SANY in promoting the systematic globalization of its high-end manufacturing capabilities, supply chain system, and brand value.

## **II. Status of Intelligent Construction in Key Area**

Characterized by “extreme flexibility, data-driven operations, and global collaboration,” the factory deeply integrates technologies such as digital twins, flexible automation, the Internet of Things, and intelligent operation management to build an advanced manufacturing platform. This platform enables rapid response to global market changes and supports efficient mixed-model production of multiple machine types.

### **1. Overall Architecture of the Smart Factory**

Guided by the core philosophy of “data-driven operations, system integration, local compliance, and global collaboration,” the factory has restructured its digital foundation. It has successfully completed digital transformation tasks covering four major transformation domains, eight core systems, six categories of key equipment, two-level control, and five major business loops. With the self-developed iMOM at its core, the factory deeply integrates systems such as SAP, WMS, CRM, and MDM. It has also successfully interfaced with key local Indonesian compliance systems, including KPPBC, SINDU, E-Nofa, and CEISA, thereby establishing a unified business platform. On this basis, 32 localized processes and 78 core business processes have been explicitly solidified, and a unified process portal has been



established. This has resulted in an operational efficiency increase of over 25%, achieving end-to-end business closure and a highly efficient upgrade in organizational collaboration.

## **2. R&D and Design: End-to-End Collaborative R&D Across Borders**

In the pre-construction phase, the factory fully applied digital simulation technology, adhering to the concept of “simulate first, build later.” First, digital twin factory modeling: a full-element 3D digital twin model encompassing workshops, production lines, and logistics was constructed in a virtual space. The overall layout, as well as personnel and material flows, were simulated and optimized to ensure an optimal design for the physical factory. Second, process simulation and verification: for complex assembly processes, simulations and commissioning of assembly sequences, robot working paths, and time balancing were carried out in a virtual environment to identify and resolve potential issues in advance. This front-loading of process verification and optimization significantly shortens the subsequent on-site commissioning period, ensuring the advanced nature and reliability of the process solutions.

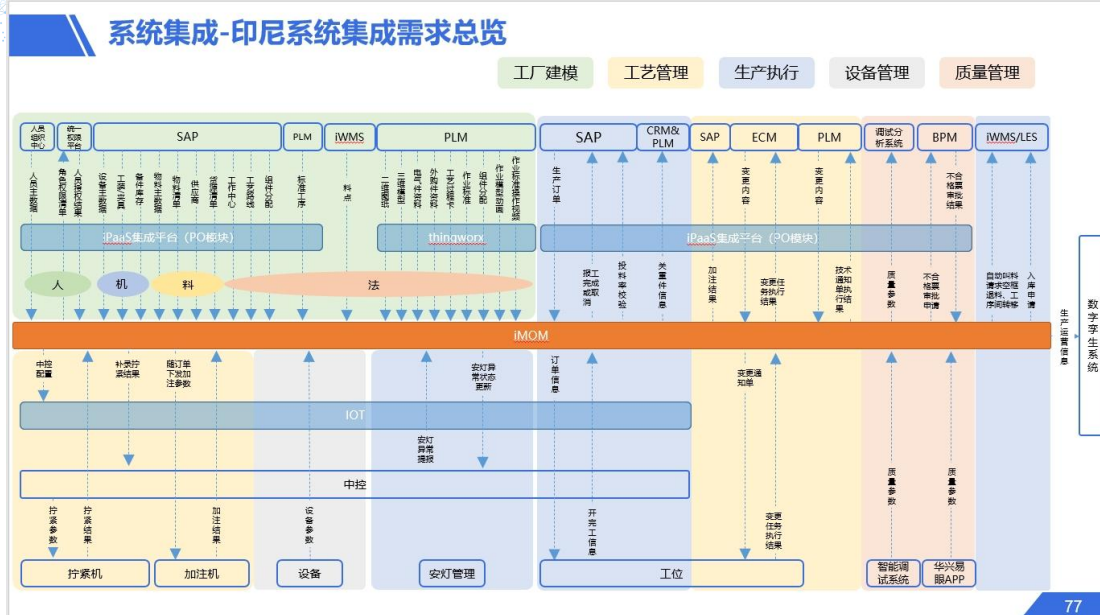


Figure 1 SANY Indonesia System Integration Diagram

### 3. Production Manufacturing: Flexible Mixed-Model Intelligent Production

The production line adopts a highly flexible and intelligent design to meet the global production demand for multiple varieties and small batches. First, integration of intelligent equipment and automated production lines: the production line integrates a series of automated equipment, including automatic turnover machines, automatic filling equipment, automatic track laying systems, and automatic tightening devices. Through standardized interfaces and programmable logic, the line can adapt to the operational requirements of different machine types and configurations, achieving automated operation and precision assurance for key assembly processes. Second, application of intelligent systems: UWB high-precision positioning technology is



deployed, equipping work-in-progress and materials with positioning tags to enable automatic real-time reporting of production progress and full transparent tracking. The AGV system, following instructions from iMOM, achieves automatic and just-in-time delivery of materials from the warehouse to line-side workstations. The central control system bridges the underlying communication protocols of all automated equipment, enabling equipment interconnectivity and centralized monitoring.



Figure 2: Production Operation Process

#### 4. Operation Management: Data-Driven Integrated Intelligent Dispatching System

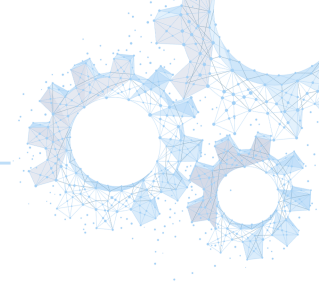
Through high integration of information systems and real-time data flow, an intelligent decision-making and dispatching center has been established. First, intelligent operation management hub: using the

self-developed iMOM (Intelligent Manufacturing Operation Management System) as the intelligent brain, it connects upward with SAP to obtain order and material information and integrates downward with WMS and automation equipment. This achieves centralized management and intelligent dispatching of the entire process, from process design and intelligent task assignment to production execution, in-process self-inspection, and finished product warehousing. Second, intelligent warehouse management: the WMS system enables refined warehouse management, realizing intelligent inbound, storage, picking, and outbound operations for materials. It also interacts in real-time with the AGV system and production line demands, ensuring high efficiency and accuracy of material supply. This achieves fully online management and precise visual monitoring of warehouse operations and material distribution.

◆ 现场已打通关键数据，实现如下主要看板，以展示业务关键数据：



Figure 3: Intelligent Manufacturing Operation Management System



### **III. Implementation Effectiveness of the Overseas Factory**

With a total investment of RMB 200 million, the factory employs 20 digital software systems with 100% independent intellectual property rights. Through nearly 1,000 data collection points, it achieves real-time data interconnection with SANY's Global Production Management and Control Center located over 3,000 kilometers away in China, enabling comprehensive upgrades in efficiency, flexibility, quality, and cost.

In terms of efficiency, the installation and commissioning of the first batch of equipment began in July 2022, and the first excavator rolled off the assembly line in just 30 days, achieving a construction speed rarely seen in the industry. The factory deploys over 500 robots of various types, with a planned output per capita as high as RMB 11 million, making it one of the overseas factories with the highest level of intelligence and the highest output per capita in China's construction machinery industry.

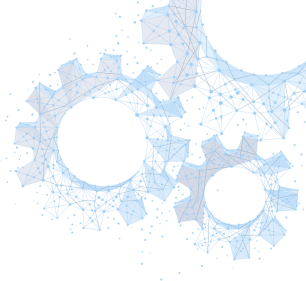
In terms of flexibility, in response to the 2025 U.S. tariffs and the UK's anti-dumping and countervailing duties trade policies, the factory successfully introduced over ten new machine types destined for European and American markets and achieved mixed-model production without large-scale modification of the production line,

taking only eight months. Over three years since production began, it has cumulatively produced over 2,000 units, with products successfully reaching high-end markets in Europe and the Americas.

In terms of quality, the automation of key processes fundamentally reduces human operational variability, significantly improving the first-pass yield of products.

In terms of cost, through precise AGV delivery, real-time UWB tracking, and the integration of WMS and iMOM systems, the factory achieves precise material distribution and real-time transparency of production progress, significantly reducing operational and logistics costs.

The construction of this factory marks a new stage for China's construction machinery industry, moving from “product export” to “intelligent manufacturing system export.”



## 摩洛哥——中信戴卡汽车零部件智能工厂

### 一、海外工厂整体情况

工厂是中信戴卡全球化战略的核心标杆，是中资企业在摩洛哥最大的工业项目，也是中信戴卡深入践行“一带一路”倡议，加强与摩洛哥工业领域合作的重要成果。工厂位于摩洛哥盖尼特拉市大西洋自贸区，自2018年起，先后建立了一期、二期铝车轮生产基地和铝铸件生产基地，一期于2019年投产。工厂占地约380亩，车轮工厂年产能达600万件，铸件工厂年产能达500万件，该基地为北非制造出第一只铝轮毂和铸件，被称为“树立中摩合作的典范”，成为中非深化经济合作、中摩共建“一带一路”、文化交流、社会交往的重要桥梁。该项目成功入选商务部“一带一路”十大典型案例，并被写入中非合作论坛成果清单。

### 二、重点环节智能化建设情况

工厂数智化建设以业务需求为导向，深度融合人工智能技术，打造覆盖生产制造、质量检测、绿色低碳、物流调度等全流程的五大核心应用场景，为制造业的智能化转型与高效发展提供了创新范式。

#### 1. 智能工厂总体架构

中信戴卡依托多年来在铝制汽车零部件全领域积累的行业数据与专业知识，结合人工智能技术，对生产制造、质量检测、物流调度、绿色低碳等关键环节进行智能化升级，打造覆

盖营销、研发、生产、运营、交付全流程的智能生产解决方案，创新部署超过 40 个的先进用例，成功打造海外智能工厂。

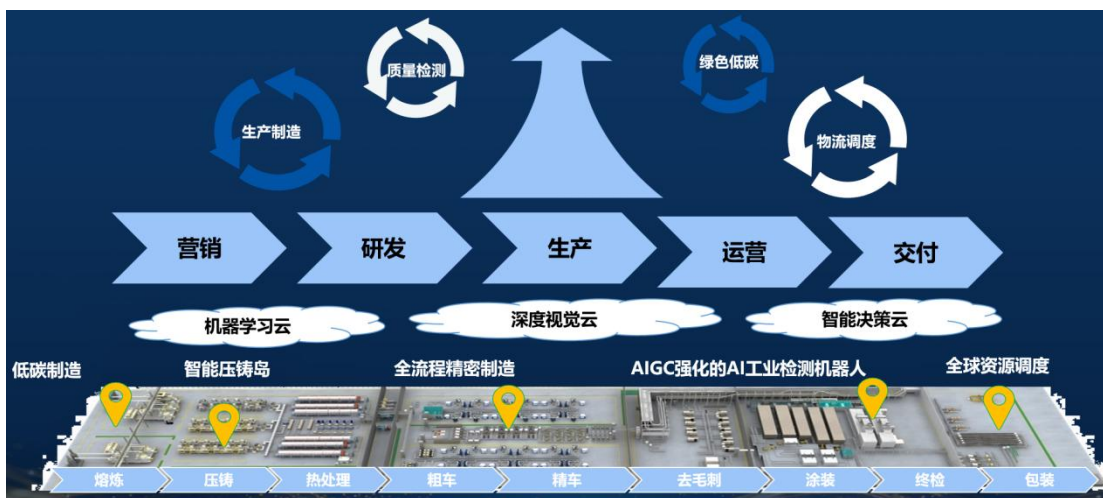


图 1 总体架构

## 2. 生产制造：全流程工艺闭环与跨工序精密制造

一是行业首创“在线 - 离线双模型迭代优化”架构，实现压铸全流程工艺参数闭环优化。基于 AI 机器学习等技术，构建多任务学习的 AI-BOX，将调机决策时间从小时级降至分钟级，从根本上保障压铸质量的稳定与高效。二是行业首创“重量管控决策大脑”，能够在铝制零部件生产过程中，精准预测换模“最佳临界窗口”，实现基于 AI 决策中枢驱动的跨工序精密制造，降低加工成本损失，显著提升金属利用率。三是行业首创基于 AIGC 的复杂部件全智能检测，利用 AIGC 自适应生成最优检测轨迹，新产品导入时间从数小时缩短至 30 分钟以内，依托全球领先的铝缺陷数据库与大模型强化算法，对 100+ 类缺陷实现精准、柔性检测。

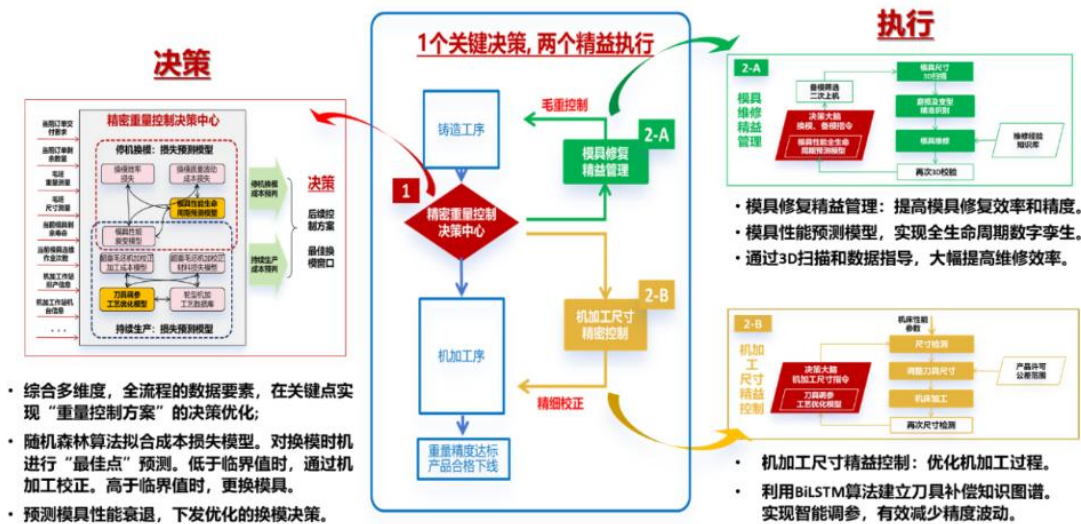


图 2 跨工序精密制造解决方案

### 3.运营管理：基于运筹模型的供应链智能管控

构建了多算法融合的需求预测与调度模型对接全球 60 余家客户系统，融合多种数据格式，通过增强学习算法将需求预测准确率提升至 80%。利用运筹优化模型动态计算全球仓库间的最优调拨路径，实现了全球供应链资源的协同调度与精益化管理。



图 3 基于运筹优化模型的全球协同调度

### 三、工厂实施成效

工厂自建设投产以来，在生产效率、质量、供应链、绿色低碳及社会效益方面取得显著突破。一是生产效率行业领先，设备

综合效率（OEE）从 73.04% 提升至 85.71%，远超行业平均水平（75%）；人均年产量从 51.6 吨增至 64.76 吨，提升 26.58%。二是质量跃升“零缺陷”，首检缺陷率从 2.25% 降至 1.55%；铸件关键缺陷一次漏检率从 0.22% 降至 0.01%，降幅达 95.45%。三是供应链精益化，成品库存比从 8.85% 降至 6.7%，降低 24.3%；库存周转天数缩短 30%，释放资金占用。四是树立绿色制造标杆，单位产品天然气消耗下降 37.15%；组织碳排放从 9.8 万吨降至 4.6 万吨，减少 53%；绿色订单收入占比从 4% 增至 53%，工厂获评非洲首家“灯塔工厂”及领先“近零碳工厂”。五是社会效益与标杆示范显著，与当地合作开发 8 个工种岗位标准，形成智能化与绿色化解决方案，已在中信戴卡全球基地复制推广。打造“全球化布局+本地化运营+智能化赋能+绿色化引领”出海新模式，获摩洛哥工业部“脱碳奖”，绿色工厂标准上升为摩洛哥国家标准。



## **Morocco—CITIC Dicastal Auto Parts Smart Factory**

### **I. Overview of the Overseas Factory**

The factory is a core benchmark of CITIC Dicastal's globalization strategy, the largest industrial project invested by a Chinese enterprise in Morocco, and a significant achievement of CITIC Dicastal in deeply implementing the "Belt and Road" initiative and strengthening industrial cooperation with Morocco. Located in the Atlantic Free Zone in Kenitra, Morocco, the factory has established Phase I and Phase II aluminum wheel production bases and an aluminum casting production base since 2018, with Phase I commencing production in 2019. The factory covers approximately 380 mu (about 25.3 hectares). The wheel factory has an annual production capacity of 6 million units, and the casting factory has an annual capacity of 5 million units. This base produced the first aluminum wheel hub and casting in North Africa, earning recognition as a "model of Sino-Moroccan cooperation." It serves as an important bridge for deepening Sino-African economic cooperation, Sino-Moroccan joint construction of the "Belt and Road," cultural exchange, and social interaction. The project has been successfully selected as one of the Ministry of

Commerce's "Top Ten Typical Cases of the Belt and Road" and was included in the outcome list of the Forum on China-Africa Cooperation.

## **II. Status of Intelligent Construction in Key Areas**

The digital and intelligent construction of the factory is driven by business needs, deeply integrating artificial intelligence technologies to create five core application scenarios covering production manufacturing, quality inspection, green and low-carbon operations, logistics scheduling, and other entire processes, providing an innovative paradigm for the intelligent transformation and efficient development of the manufacturing industry.

### **1. Overall Architecture of the Smart Factory**

Leveraging years of industry data and expertise accumulated in the field of aluminum automotive components, combined with AI technologies, CITIC Dicastal has intelligently upgraded key processes such as production manufacturing, quality inspection, logistics scheduling, and green low-carbon operations. It has created an intelligent production solution covering the entire process of marketing, R&D, production, operations, and delivery. Over 40 advanced use cases have been innovatively deployed, successfully



establishing an overseas Smart Factory.

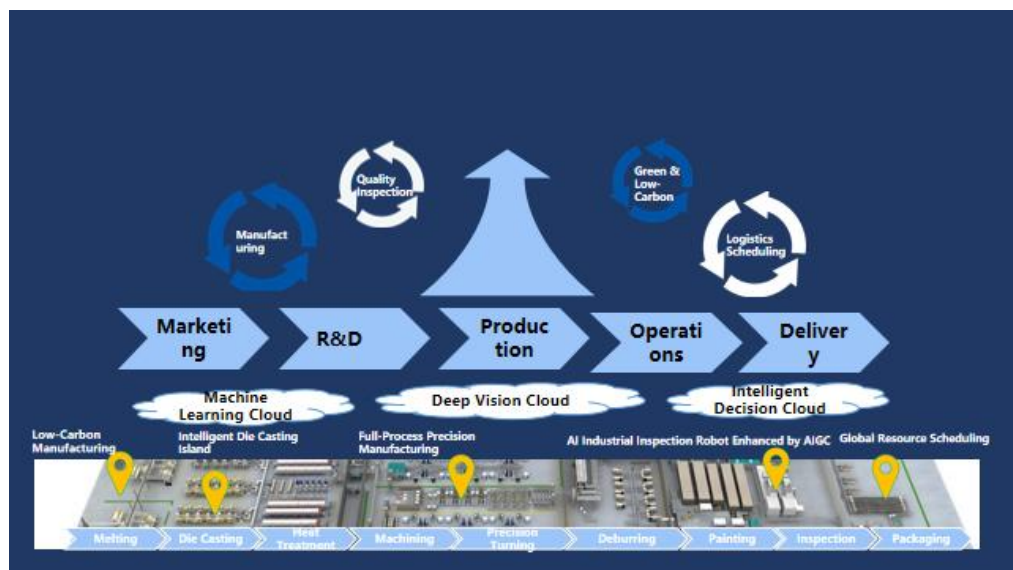


Figure 2: Overall Architecture

## 2. Production Manufacturing: Closed-Loop Whole-Process and Cross-Process Precision Manufacturing

First, an industry-first "online-offline dual-model iterative optimization" architecture achieves closed-loop optimization of process parameters throughout the die-casting process. Based on AI machine learning and other technologies, an AI-BOX for multi-task learning has been developed, reducing decision-making time for machine adjustment from hours to minutes, fundamentally ensuring the stability and efficiency of die-casting quality. Second, an industry-first "weight management decision-making brain" can accurately predict the "optimal changeover window" during the production of aluminum components, enabling cross-process precision manufacturing driven by an AI decision-making hub, reducing

processing cost losses and significantly improving metal utilization. Third, an industry-first AIGC-based fully intelligent inspection of complex components uses AIGC to adaptively generate optimal inspection trajectories, reducing new product introduction time from several hours to less than 30 minutes. Relying on a globally leading aluminum defect database and large-model reinforcement algorithms, it achieves precise and flexible inspection for over 100 defect types.

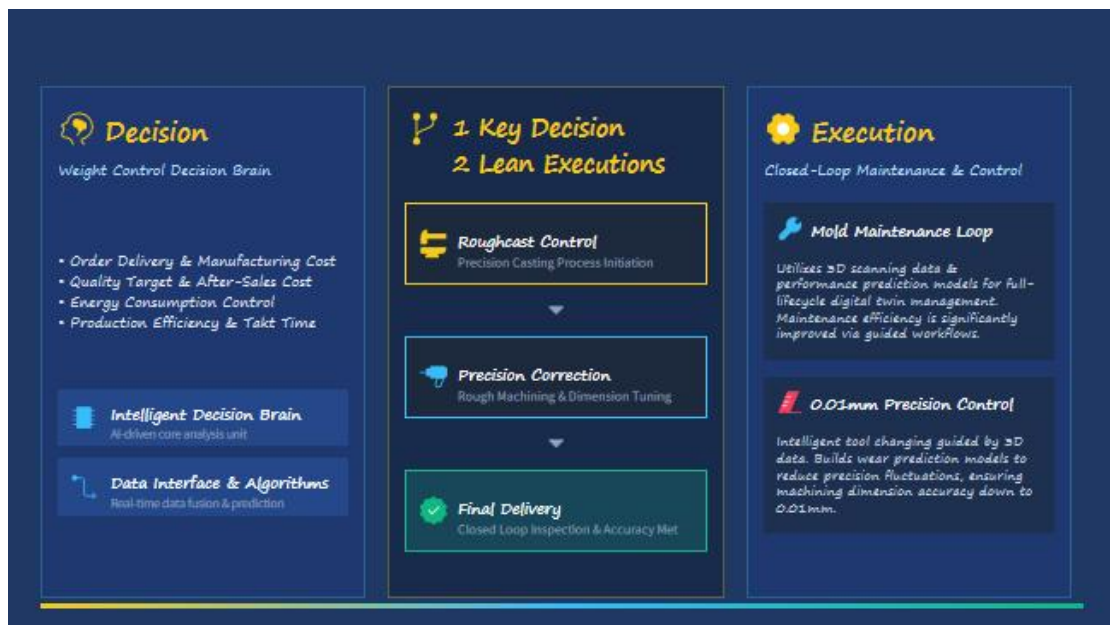
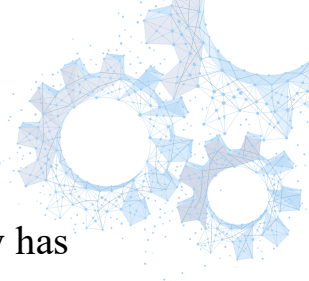


Figure 2: Cross-Process Precision Manufacturing Solution

### 3. Operation Management: Intelligent Supply Chain Control Based on Operations Research Models

A multi-algorithm fused demand forecasting and scheduling model has been constructed, interfacing with over 60 customer systems globally and integrating multiple data formats. Through



reinforcement learning algorithms, the demand forecast accuracy has been improved to 80%. Using operations research optimization models, the optimal inter-warehouse transfer routes are dynamically calculated, enabling collaborative scheduling and lean management of global supply chain resources.

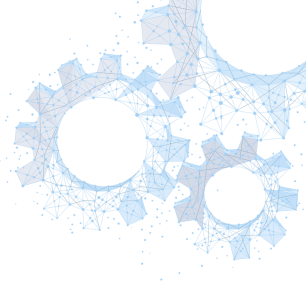


Figure 3: Global Collaborative Scheduling Based on Operations Research Optimization Models

### III. Implementation Effectiveness of the Overseas Factory

Since its construction and commissioning, the factory has achieved significant breakthroughs in production efficiency, quality, supply chain, green and low-carbon performance, and social benefits. First, leading production efficiency in the industry: Overall Equipment Effectiveness (OEE) increased from 73.04% to 85.71%, far exceeding the industry average of 75%; annual output per capita increased from 51.6 tons to 64.76 tons, a rise of 26.58%. Second, a leap to "zero-defect" quality: The first inspection defect rate decreased from 2.25%

to 1.55%; the first-time miss rate for key casting defects decreased from 0.22% to 0.01%, a reduction of 95.45%. Third, lean supply chain: The finished goods inventory ratio decreased from 8.85% to 6.7%, a reduction of 24.3%; inventory turnover days shortened by 30%, freeing up working capital. Fourth, establishing a benchmark for green manufacturing: Natural gas consumption per unit product decreased by 37.15%; organizational carbon emissions decreased from 98,000 tons to 46,000 tons, a reduction of 53%; the share of green order revenue increased from 4% to 53%. The factory has been recognized as Africa's first "Lighthouse Factory" and a leading "Near-Zero Carbon Factory." Fifth, significant social benefits and benchmark demonstration effects: Collaborating with local partners, it has developed job standards for 8 types of work, forming intelligent and green solutions that have been replicated and promoted across CITIC Dicastal's global bases. It has created a new overseas expansion model characterized by "global layout + localized operation + intelligent empowerment + green leadership," winning the "Decarbonization Award" from the Moroccan Ministry of Industry, and its green factory standards have been adopted as Moroccan national standards.



## 塞尔维亚——玲珑轮胎智能工厂

### 一、海外工厂整体情况

工厂位于塞尔维亚兹雷尼亚宁自贸区，是山东玲珑轮胎股份有限公司“7+5”全球化战略<sup>1</sup>核心标杆，是中国轮胎行业在欧洲建成的首个全流程智能工厂，同时也是塞尔维亚迄今最大的绿地投资项目。工厂于2019年3月奠基，2024年9月正式量产，项目总投资16.35亿美元，规划用地97公顷，总建筑面积约50万平方米，具备年产1362万条高性能子午线轮胎的能力，二期扩建后将新增110万条产能，并配套再生胶、光伏等绿色项目。产品覆盖高端配套、替换市场与特种轮胎，已快速通过大众、奥迪、宝马、福特等国际一线车企审核，成为中国轮胎切入欧洲高端供应链的标志性基地，投产半年即实现盈利，欧洲市场认可度与盈利能力同步快速提升。

<sup>1</sup> 国内7大生产基地：山东招远、山东德州、广西柳州、湖北荆门、吉林长春、陕西铜川、安徽六安；  
海外5大生产基地：泰国罗勇府工厂、塞尔维亚兹雷尼亚宁工厂已投产，另外3大海外工厂在规划中。



图 1 玲珑欧洲兹雷尼亚宁智能工厂

## 二、重点环节智能化建设情况

工厂以工业 4.0 为标准，秉持精益化、绿色化、数智化理念，深度融合人工智能、数字孪生、5G、工业互联网、工业机器人等技术，纵向贯通 OT 与 IT，横向打通研、产、供、销、服、财、法全业务域，构建端到端全价值链智能制造体系，打造轮胎行业海外智能工厂典范。

### 1. 智能工厂总体架构

工厂采用“数字底座+业务中台+应用场景”三层架构，以 SAP 为核心，深度集成 PLM、MES、APS、WMS、QMS、EAM 等自主工业软件，打通欧洲本地合规、税务、物流系统，实现数据同源、业务同频与全球协同。建成统一流程门户与跨国协同平台，固化本地化核心业务流程，实现计划、生产、质量、设备、物流、成本全闭环管控，实现运营效率显著提升，关键决策响应速度加快，形成可复制、可推广的海外轮胎智能制造架构模式。

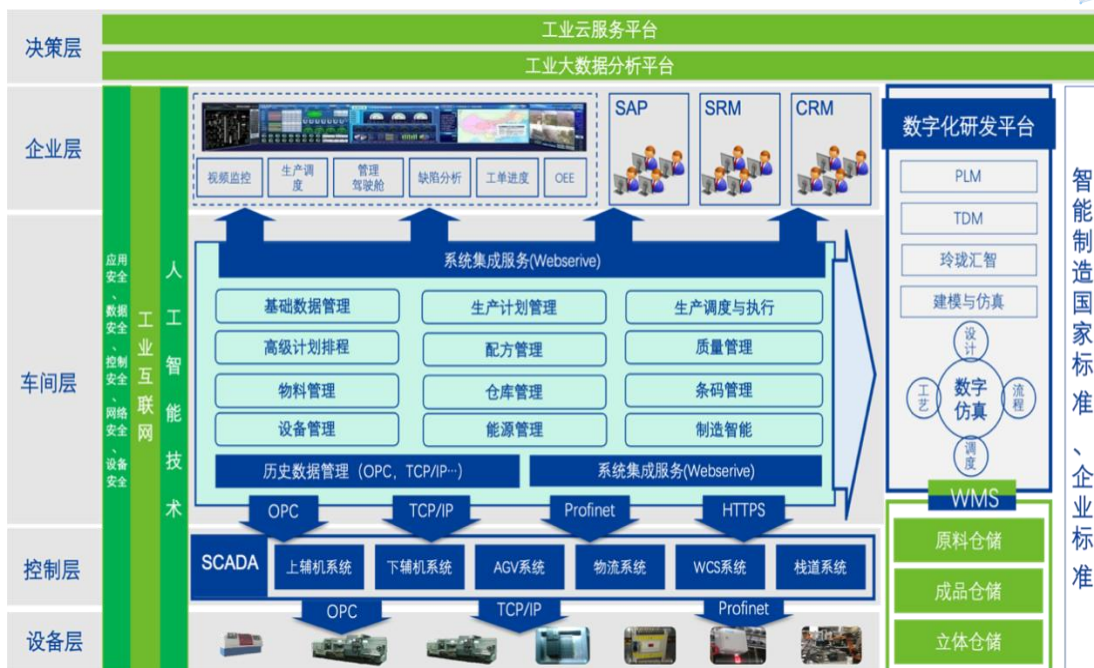


图2 玲珑欧洲智能工厂总体架构图

## 2. 生产制造：全要素端到端协同制造

围绕轮胎制造全流程，构建以MES为核心的数字化管控系统，实现对人、机、料、法、环、测的全流程数字化管控。一是构建智能装备集群，采用全自动智能密炼系统、智能挤出压延联动线、高精度自动裁断、智能成型机组、液压智能硫化机组，使得关键工序机器人替代率达100%，成型、硫化精度与一致性行业领先。二是X光自动检测，引入AI X-Ray系统，构建双模融合训练架构，通过有监督学习精准识别已知缺陷，无监督小样本学习捕获未知隐患，并搭载精准定位测量算法，彻底消除视觉疲劳与主观判断造成的漏检盲区，核心缺陷检出率大幅提升近3%。三是智能物流与无人转运，配置激光导航AGV/AMR、AS/RS立体仓库、全自动输送系统，实现原料、半成品、成品无人化转运、智能存储、精准调度，物流效率提



驶舱，实时可视化展示生产、质量、设备、能耗、物流等关键指标，支撑管理层远程监控、异常预警与智能决策。

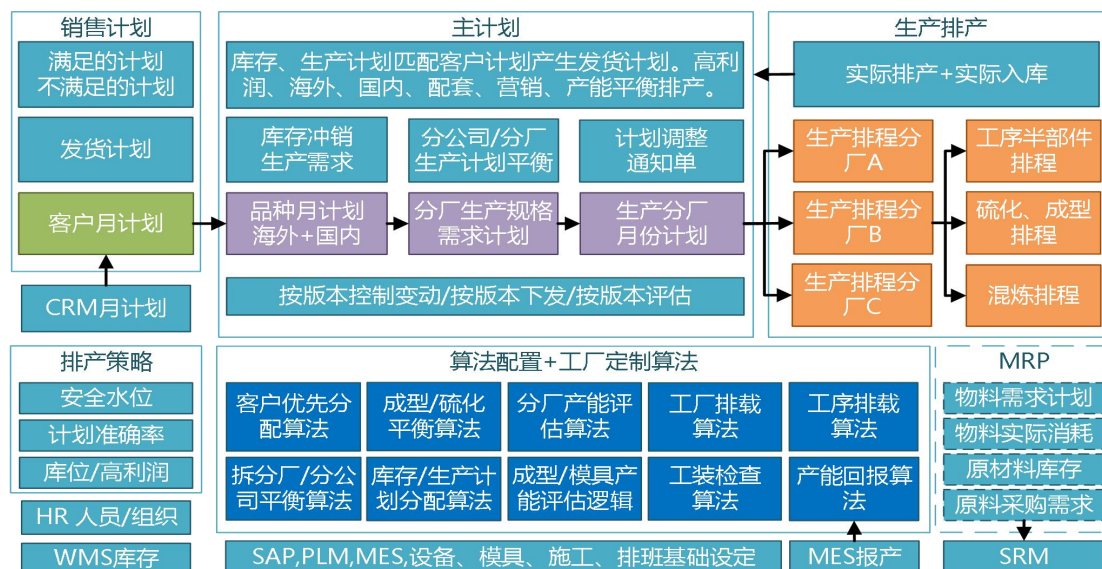


图4 轮胎行业产销平衡管理平台

### 三、工厂实施成效

作为中国轮胎在欧洲的首座全流程智能工厂，实现了全领域智能化与全流程自动化。整体效率与设备综合效率双升30%以上，单胎生产周期压缩至22分钟，交货期由35天骤降至5天，树立了出海高端智造新标杆。在跨国协同方面，率先打通研产供销服财法八大业务域，构建“中国总部—欧洲工厂”数据、业务、价值流三位一体协同网络，同规模用工从约5000人优化至2200人，单位产值能耗降至行业均值的85%，打造可复制的海外数字化运营范式。在品质提升层面，一次合格率达99.6%，不良品率降低超50%，快速通过大众、奥迪、宝马、福特Q1等高端认证，精准适配欧洲严苛标准，投产即实现盈利，半钢与全钢产销率分别逼近95%和超100%，智能化成果高效转化为市场竞争力。在绿

色供应链方面，依托中欧定制班列与持续提升的本地制造率保障供应韧性。水资源回用率超 90%，碳排放强度下降 30%，高标准通过欧洲 ESG 与绿色工厂审核，实现降本增效与低碳发展的深度融合。



## Serbia—Linglong Tire Smart Factory

### I. Overview of the Overseas Factory

Located in the Zrenjanin Free Zone in Serbia, the factory is a core benchmark of Shandong Linglong Tire Co., Ltd.'s "7+5" globalization strategy<sup>2</sup>. It is the first full-process Smart Factory built by a Chinese tire company in Europe and the largest greenfield investment project by a Chinese enterprise in Serbia to date. Construction began in March 2019, and mass production officially started in September 2024. The total investment in the project is 1.635 billion USD, covering a planned area of 97 hectares with a total construction area of approximately 500,000 square meters. It has an annual production capacity of 13.62 million high-performance radial tires. The Phase II expansion will add a further 1.1 million units of capacity and will include complementary green projects such as reclaimed rubber and photovoltaics. The products cover high-end original equipment (OE), replacement markets, and specialty tires. The factory has quickly passed audits from leading international automakers, including Volkswagen, Audi, BMW, and Ford, becoming a landmark base for

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<sup>2</sup> Domestic 7 major bases: Zhaoyuan, Shandong; Dezhou, Shandong; Liuzhou, Guangxi; Jingmen, Hubei; Changchun, Jilin; Tongchuan, Shaanxi; Lu'an, Anhui.  
Overseas 5 major bases: Rayong, Thailand; Zrenjanin, Serbia (operational); three other overseas bases under planning.

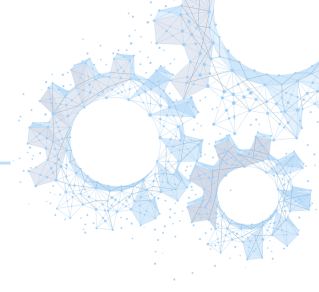
Chinese tires to enter the European high-end supply chain. It achieved profitability within six months of production, with both market recognition and profitability in Europe rapidly increasing.



Figure 1: Linglong Tire Smart Factory

## II. Status of Intelligent Construction in Key Areas

Built to Industry 4.0 standards and adhering to the principles of lean, green, and digital intelligence, the factory deeply integrates technologies such as artificial intelligence, digital twins, 5G, the industrial internet, and industrial robots. It vertically integrates OT and IT and horizontally connects the entire business domains of R&D, production, procurement, sales, service, finance, and legal, establishing an end-to-end, full-value-chain intelligent manufacturing system and creating a model for overseas intelligent factories in the



tire industry.

## **1. Overall Architecture of the Smart Factory**

The factory adopts a three-layer architecture of "digital foundation + business middleware + application scenarios." With SAP at its core, it deeply integrates independent industrial software such as PLM, MES, APS, WMS, QMS, and EAM. It has successfully interfaced with local European compliance, tax, and logistics systems, achieving data homogeneity, business synchronization, and global collaboration. A unified process portal and cross-border collaboration platform have been established, solidifying localized core business processes. This enables closed-loop management and control of planning, production, quality, equipment, logistics, and costs, resulting in significantly improved operational efficiency and faster response times for key decisions, thus forming a replicable and scalable architectural model for overseas intelligent tire manufacturing.

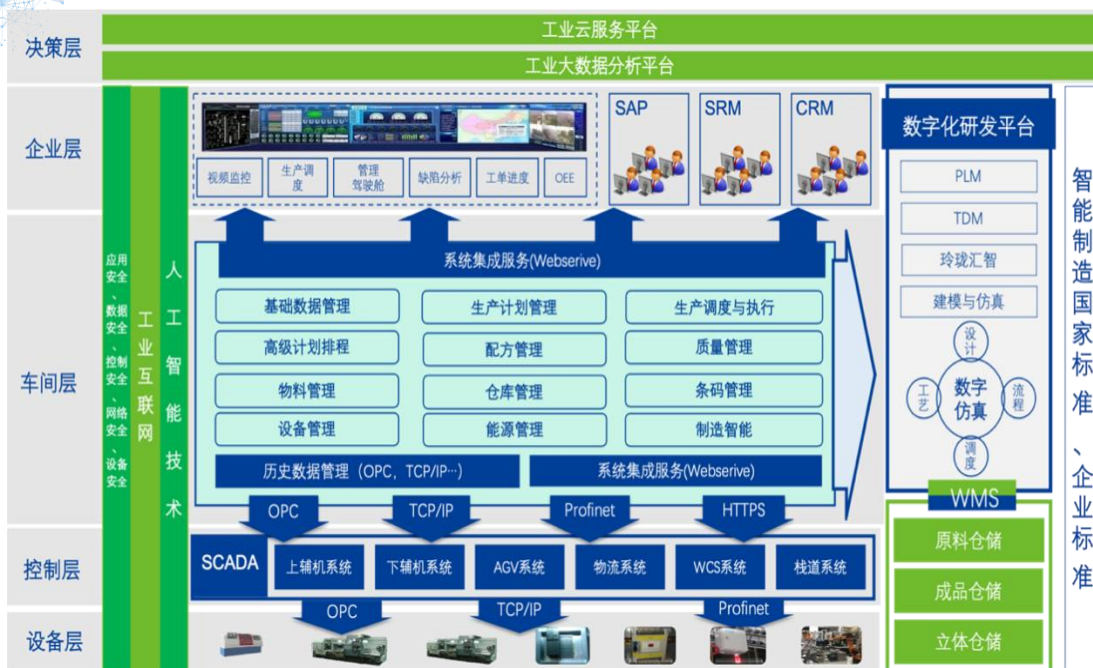


Figure 2: Factory Overall Architecture Diagram

## 2. Production Manufacturing: Full-Element End-to-End Collaborative Manufacturing

Centered around the entire tire manufacturing process, a digital management and control system with MES as its core has been built, enabling full-process digital management of people, machines, materials, methods, environment, and measurement. First, an intelligent equipment cluster: Fully automatic intelligent mixing systems, intelligent extrusion and calendaring lines, high-precision automatic cutting systems, intelligent building machines, and hydraulic intelligent curing presses are adopted, achieving a 100% robot substitution rate for key processes, with building and curing precision and consistency leading the industry. Second, automatic X-



ray inspection: An AI X-Ray system is introduced, employing a dual-model fusion training architecture. Supervised learning accurately identifies known defects, while unsupervised few-shot learning captures unknown hidden risks. Equipped with precise positioning and measurement algorithms, it completely eliminates blind spots in inspection caused by visual fatigue and subjective judgment, significantly improving the detection rate of core defects by nearly 3%. Third, intelligent logistics and unmanned transport: Laser-guided AGVs/AMRs, AS/RS automated warehouses, and fully automatic conveyor systems are deployed, achieving unmanned transport, intelligent storage, and precise scheduling of raw materials, semi-finished products, and finished goods, increasing logistics efficiency by over 40%. Fourth, data acquisition and closed-loop control: Thousands of sensors are deployed throughout the entire process, collecting real-time parameters such as temperature, pressure, time, speed, and thickness, enabling real-time monitoring, automatic correction, and full traceability.

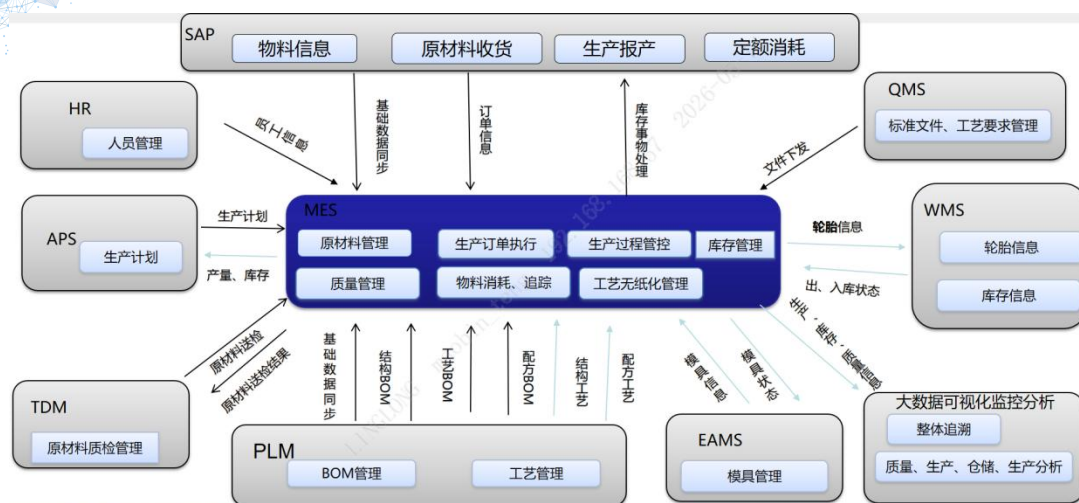


Figure 3: Factory Digital Integration Platform Centered on MES

### 3. Operation Management: Full-Scenario Data-Driven Intelligent Decision-Making

With MPS, APS, and MRP as its core, an integrated operation management platform has been built, achieving full-link connectivity from order to delivery, production to cost, and procurement to inventory, adapted to European compliance and efficient management requirements. First, supply chain collaboration: Integrating internal and external supply chain systems to connect procurement, inventory, production, transportation, and sales, synchronizing data with the SAP system to generate financial vouchers, and creating an integrated business and financial management platform. Second, full-lifecycle quality management: Using the QMS system to integrate production, inspection, and after-sales data, an AI quality early warning model is built, enabling preventive actions before issues arise, control during



production, and traceability after delivery, meeting the stringent audit requirements of high-end European automakers. Third, predictive maintenance for equipment: Based on EAM and AI technologies, data such as vibration, temperature, and current are collected to enable fault prediction and preventive maintenance, reducing unplanned downtime by over 50%. Fourth, intelligent decision-making cockpit: A 3D digital twin operations cockpit is built, displaying key metrics such as production, quality, equipment, energy consumption, and logistics in real-time, supporting remote monitoring, anomaly alerts, and intelligent decision-making for management.

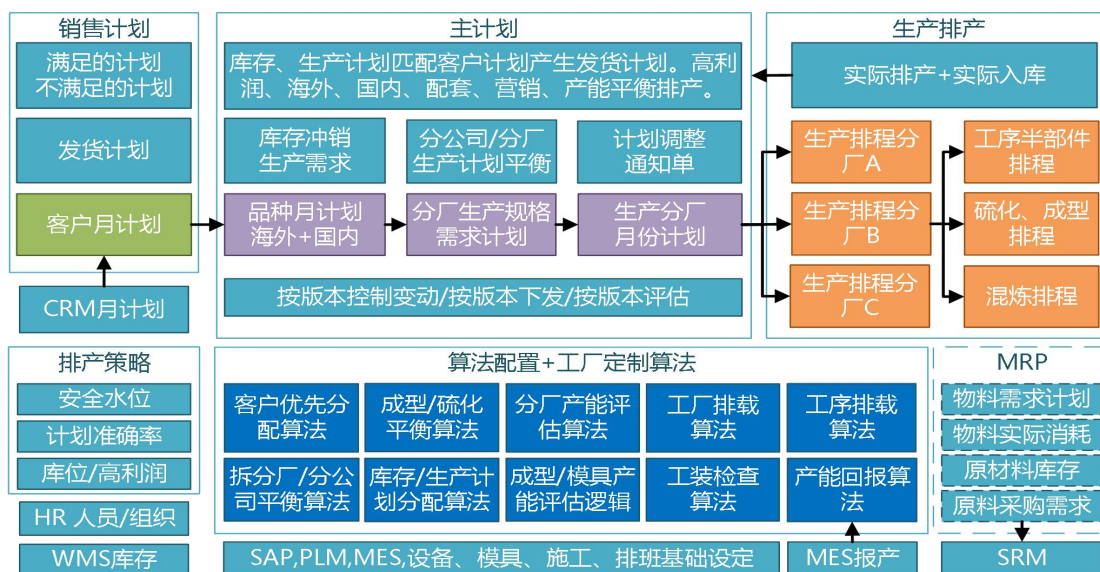
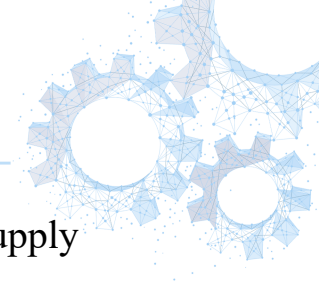


Figure 4: Tire Industry Production-Sales Balance Management Platform

### III. Implementation Effectiveness of the Overseas Factory

As the first full-process intelligent tire factory built by a Chinese company in Europe, it has achieved full-area intelligence and full-process automation. Overall efficiency and Overall Equipment Effectiveness (OEE) have both increased by more than 30%. The production cycle time per tire has been reduced to 22 minutes, and the delivery time has dramatically decreased from 35 days to 5 days, setting a new benchmark for high-end intelligent manufacturing overseas. In terms of cross-border collaboration, it is the first to integrate eight business domains (R&D, production, procurement, sales, service, finance, legal), building a "China HQ - Europe Factory" tripartite collaborative network of data, business, and value streams. The workforce for the same scale of production has been optimized from approximately 5,000 to 2,200, energy consumption per unit of output value is reduced to 85% of the industry average, creating a replicable overseas digital operation paradigm. In terms of quality improvement, the first-pass yield reaches 99.6%, and the defect rate has been reduced by over 50%. It has quickly passed high-end certifications such as those from Volkswagen, Audi, BMW, and Ford Q1, precisely adapting to stringent European standards. It achieved profitability immediately after production started, with production-sales ratios for both half-steel and all-steel tires approaching 95% and exceeding 100%, respectively, effectively translating intelligent



achievements into market competitiveness. In terms of green supply chain, relying on dedicated China-Europe railway trains and an increasing local manufacturing rate ensures supply resilience. The water reuse rate exceeds 90%, carbon emission intensity has decreased by 30%, and it has successfully passed high-standard European ESG and green factory audits, achieving a deep integration of cost reduction, efficiency improvement, and low-carbon development.

## 坦桑尼亚——华新建材水泥生产智能工厂

### 一、海外工厂整体情况

工厂坐落于坦桑尼亚坦噶区，是华新水泥践行“一带一路”倡议、布局非洲市场的核心战略标杆，也是中国企业在坦桑尼亚投资的最大单体建材项目。该工厂最初是一条严重亏损、长期停产的老旧生产线。2019年，华新水泥正式签订股权收购协议，并于2020年全面接管运营。面对停产遗留问题，华新果断注入资金与技术，启动项目数智化升级改造，并配套建设余热发电系统。2024年，二期日产4500吨水泥熟料生产线顺利投产，工厂总产能大幅提升，一举成为坦桑尼亚目前最大的水泥企业。工厂主营水泥的生产与销售，产品广泛应用于坦桑尼亚各大重点基础设施工程，如坦噶港二期扩建、莫罗格罗水电大坝、SGR中央电气化铁路等，为东非地区的经济建设提供了坚实的建材保障。

### 二、重点环节智能化建设情况

工厂以全面数字化改造为核心，构建了“管理-生产-物流”一体化的数字底座，打通了从采购、财务、生产到物流发运的数据孤岛，实现跨国别、跨地域的全链条数智化贯通。通过全链路的数智化赋能，有效保障业务流程的绝对规范与高效运作，大幅降低管理成本与运营风险，为中国企业海外并购资产的“提质增效”提供了数字化改造样板。



图 1 华新建材智能工厂总体架构图

总体架构以国产数智化技术为基石，底层通过 IoT 汇集设备数据，中层部署华新自研工业 APP（HIAC/HOPE 等），上层打通 ERP 与云端协同办公生态，形成“云-边-端”一体化布局。

### 1. 研发设计：虚拟调试驱动工艺优化

依托华新水泥百年的工艺沉淀与数字化研发体系，项目在设计阶段即引入数字化建模与仿真技术。针对非洲地区原燃材料（如高硫煤、废旧轮胎等替代燃料）的特性，项目通过虚拟调试优化了预热器、分解炉及回转窑的工艺参数匹配，确立了“新型干法生产技术+大比例替代燃料”的低碳生产模型。这一设计前置的数字化手段，为后续 HIAC 系统的稳定控制奠定了数据基础。



图 2 华新建材海外水泥工厂全景

### 2. 生产制造：算法驱动的智能生产

工厂在生产核心环节全面部署华新自研的智能控制系统，实现了从“经验主义”到“算法驱动”的跨越：一是**华新智能先进控制系统（HIAC）**。基于阿里云工业智能控制优化平台开发，作为水泥窑的“自动驾驶”大脑，可实现每秒多次的自动寻优调整。它成功攻克了大比例使用替代燃料（RDF）导致的工况扰动难题，在保障分解炉燃煤替代率超 80%的同时，实现生产过程的极度稳定。二是**华新海外生产专家平台（HOPE）**。作为海外工厂的工业数据枢纽，HOPE 系统支持多协议设备接入，可实时采集与计算全厂运行数据，并提供预警分析及自动报表生成功能，满足生产、质量、维修等核心业务的一站式监控与精益管理需求。三是**智能监控识别系统（HAVEN）**。在关键节点部署 AI 视觉分析，针对海外工厂的治安与物资管理痛点，开发了 AI 视觉点包系统

与防盗监控系统，有效防范物资流失，为海外工厂的稳定运营筑牢安全防线。



图3 华新智能先进控制系统

### 3. 运营管理：业财跨国一体化，供应链智慧协同

工厂打破了跨国企业管理中常见的“数据孤岛”与“流程割裂”现象，构建了高度集成的数字化运营生态：一是业财一体化与本土合规。以国产金蝶云 ERP 为中枢，创新性实现与坦桑尼亚当地税务系统（如 TAXONE 等）及银行系统的数据直连。这不仅实现了财务业务的高效协同，更确保了企业运营完全符合当地复杂的财税合规要求。二是跨国协同与移动办公。结合钉钉与 Workeasy 平台，搭建跨越中非两地的多语言协作办公网络，实现内部审批流与人力管理的即时响应与透明化。三是智慧物流与供应链。自主研发物流采购系统，将订单、采购、仓储与厂外物流发运无缝衔接，通过云端数据联动（如与华为云合作的跨国 IDC

机房上云项目），大幅提升海外供应链的响应速度与可靠性，降低库存与运维成本。

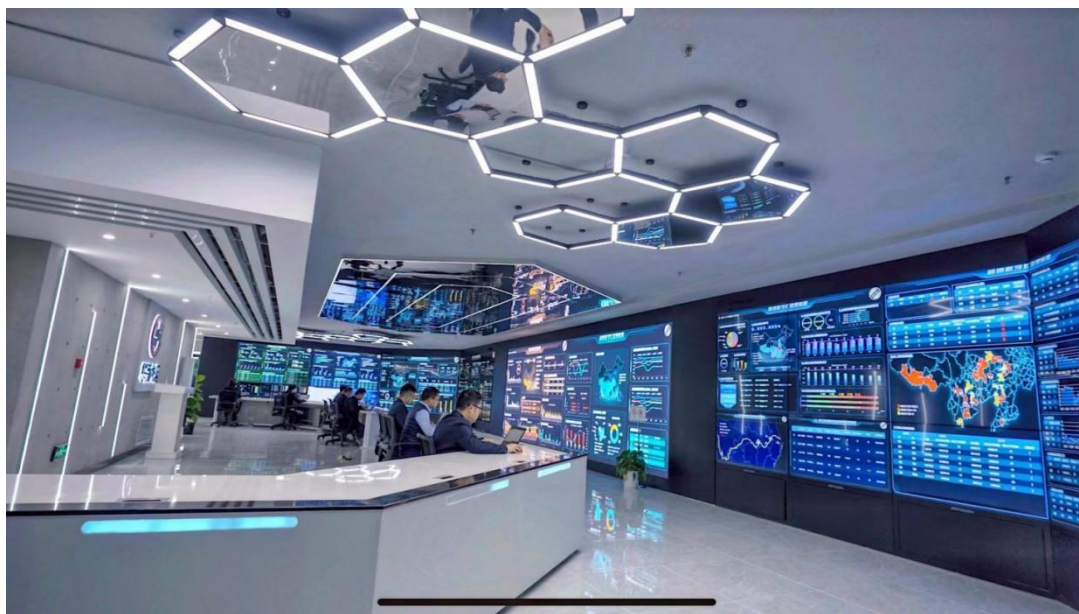


图 4 华新建材数字化运营管控中心

### 三、工厂实施成效

**一是提质增效，扭亏为盈。**数智化改造彻底激活了停产资产，水泥销量与营业收入连年刷新历史纪录，人均劳动生产率较接管前实现数倍增长。**二是降本减碳，绿色制造。**借助 HIAC 等智能系统，工厂在消化城市废弃物替代燃料的同时，显著降低煤耗与碳排放强度，单位熟料综合能耗达到行业领先水平。**三是合规避险，优化管理。**业财数据与物流信息的全链路透明化，有效规避人为操作漏洞，大幅降低跨国运营的财务与管理风险。此外，工厂成功将金蝶、钉钉、阿里云等国产数字化管理工具与坦桑尼亚本土的政府税务、金融系统无缝对接，形成了“中国技术内核+本地化生态适配”的出海样板。同时，针对海外老旧生产线基础薄弱、治安环境复杂等痛点，工厂不盲目追求全盘更换硬件，而

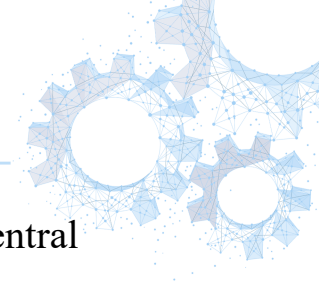


是通过部署自研的 HOPE 数据平台，利用 HIAC 算法与 HAVEN 视觉 AI 进行“软硬结合”的边缘计算赋能，打造了适配海外老旧工厂改造的“边缘计算+AI”解决方案。

## **Tanzania—Huaxin Building Materials Cement Production Smart Factory**

### **I. Overview of the Overseas Factory**

Located in the Tanga Region of Tanzania, the factory is a core strategic benchmark for Huaxin Cement Co., Ltd. in implementing the "Belt and Road" initiative and expanding into the African market. It is also the largest single building materials project invested by a Chinese company in Tanzania. The factory originally was an aged production line that had suffered severe losses and long-term shutdown. In 2019, Huaxin Cement formally signed an equity acquisition agreement and took over operations in 2020. Facing the legacy issues of the shutdown, Huaxin decisively injected capital and technology, initiating a digital and intelligent upgrade project for the facility, along with constructing a waste heat power generation system. In 2024, the Phase II production line with a daily capacity of 4,500 tons of cement clinker was successfully commissioned, significantly boosting the factory's total capacity and making it the largest cement enterprise in Tanzania. The factory's main business is the production and sales of cement, with products widely used in major infrastructure projects throughout Tanzania, such as the Phase II expansion of Tanga



Port, the Morogoro Hydropower Dam, and the SGR Central Electrified Railway, providing a solid foundation of building materials for economic development in East Africa.

## **II. Status of Intelligent Construction in Key Areas**

Centered on a comprehensive digital transformation, the factory has built an integrated digital foundation covering "management-production-logistics," breaking down data silos spanning procurement, finance, production, and logistics dispatch. This achieves full-chain digital intelligence integration across countries and regions. Through full-chain digital intelligence empowerment, it effectively ensures absolute standardization and high efficiency of business processes, significantly reducing management costs and operational risks, providing a digital transformation model for "improving quality and efficiency" of assets acquired overseas by Chinese enterprises.



Figure 1: Huaxin Building Materials Smart Factory Overall Architecture Diagram

The overall architecture is based on domestic digital intelligence technology. At the bottom layer, IoT aggregates equipment data; the middle layer deploys Huaxin's self-developed industrial APPs (HIAC/HOPE, etc.); the top layer connects ERP with cloud-based collaborative office ecosystems, forming a "cloud-edge-device" integrated layout.

## 1. R&D and Design: Virtual Commissioning Driving Process Optimization

Leveraging Huaxin Cement's century-old process know-how and digital R&D system, digital modeling and simulation technologies were introduced from the design phase. Targeting the characteristics of raw materials and fuels in Africa (such as high-sulfur coal,



alternative fuels like waste tires), the project optimized the matching of process parameters for the preheater, calciner, and rotary kiln through virtual commissioning, establishing a low-carbon production model of "new dry process technology + high-proportion alternative fuel substitution." This front-loaded digital design approach laid the data foundation for the subsequent stable control of the HIAC system.



Figure 2: Panoramic View of Huaxin Building Materials Overseas Cement Factory

## **2. Production Manufacturing: Algorithm-Driven Intelligent Production**

The factory has fully deployed Huaxin's self-developed intelligent control systems in core production processes, achieving a shift from "experience-based" to "algorithm-driven" operations:

First, Huaxin Intelligent Advanced Control System (HIAC): Developed based on Alibaba Cloud's Industrial Intelligent Control Optimization Platform, it serves as the "autopilot" brain for the cement kiln, capable of performing automatic optimization adjustments multiple times per second. It successfully overcomes the process disturbances caused by using high proportions of alternative fuel (RDF), ensuring the stability of the production process while achieving a coal substitution rate in the calciner exceeding 80%.

Second, Huaxin Overseas Production Expert Platform (HOPE): As the industrial data hub for the overseas factory, the HOPE system supports multi-protocol device access, enabling real-time data collection and calculation of factory-wide operating parameters. It provides early warning analysis and automatic report generation, meeting the one-stop monitoring and lean management needs of core business processes such as production, quality, and maintenance.

Third, Intelligent Monitoring and Identification System (HAVEN): AI visual analytics are deployed at key nodes. Addressing the security and material management challenges specific to overseas factories, an AI visual bag counting system and anti-theft monitoring system have been developed, effectively preventing material loss and building a strong safety line for the stable operation of the overseas factory.



Figure 3: Huaxin Intelligent Advanced Control System

### 3. Operation Management: Integrated Cross-Border Finance and Business, Smart Supply Chain Collaboration

The factory breaks the common phenomena of "data silos" and "process fragmentation" in cross-border enterprise management, building a highly integrated digital operation ecosystem:

First, integrate finance and business with local compliance: Using the domestic Kingdee Cloud ERP as the hub, it innovatively achieves direct data connection with the Tanzanian local tax system (e.g., TAXONE) and banking systems. This not only enables efficient collaboration between finance and business but also ensures that operations fully comply with complex local fiscal and tax compliance

requirements.

Second, cross-border collaboration and mobile office: Combining the DingTalk and Workeasy platforms, a multilingual collaborative office network spanning China and Africa has been built, enabling instant response and transparency for internal approval workflows and human resource management.

Third, smart logistics and supply chain: A self-developed logistics procurement system seamlessly connects orders, procurement, warehousing, and off-site logistics dispatch. Through cloud-based data collaboration (e.g., the cross-border IDC cloud project in cooperation with Huawei Cloud), it significantly improves the responsiveness and reliability of the overseas supply chain, reducing inventory and operational maintenance costs.

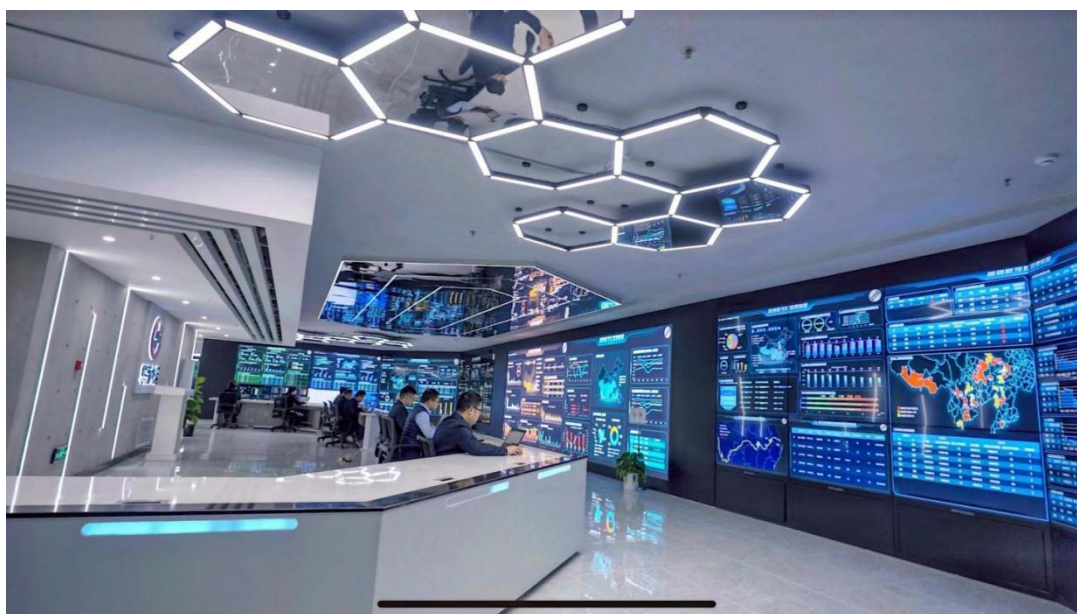
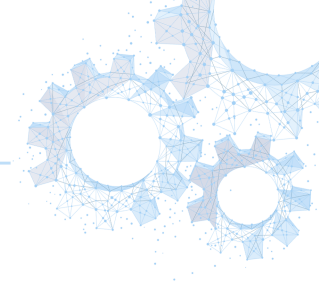


Figure 4: Huaxin Building Materials Digital Operation Control Center



### **III. Implementation Effectiveness of the Overseas Factory**

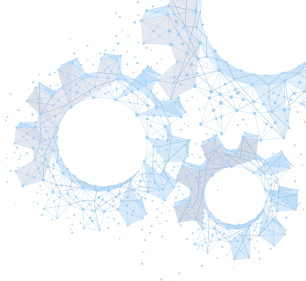
First, improving quality and efficiency, turning losses into profits: The digital intelligence transformation completely revitalized the idle assets. Cement sales volume and operating revenue have repeatedly set new historical records, and labor productivity per capita has increased several times compared to the pre-acquisition period.

Second, reducing costs and carbon emissions, green manufacturing: With the help of intelligent systems like HIAC, the factory significantly reduces coal consumption and carbon emission intensity while consuming alternative fuels from municipal waste. The comprehensive energy consumption per unit of clinker has reached a leading level in the industry.

Third, ensuring compliance and mitigating risks, optimizing management: Full-link transparency of financial, business, and logistics data effectively avoids human manipulation loopholes and significantly reduces financial and management risks in cross-border operations.

Furthermore, the factory has successfully integrated domestic digital management tools such as Kingdee, DingTalk, and Alibaba Cloud

with Tanzania's local government tax and financial systems, creating an overseas expansion model of "Chinese technology core + localized ecosystem adaptation." Addressing the weak infrastructure of the aged overseas production line and the complex security environment, the factory avoided blindly replacing all hardware. Instead, by deploying the self-developed HOPE data platform and utilizing HIAC algorithms and HAVEN visual AI for "software-hardware combined" edge computing empowerment, it has created an "edge computing + AI" solution suitable for renovating old overseas factories.



## 泰国——长安汽车整车制造智能工厂

### 一、海外工厂整体情况

工厂是长安汽车“海纳百川”战略在东南亚的海外桥头堡，肩负着打造长安汽车海外智能标杆工厂的使命，也是规划产能最大、智能化程度最高的海外基地。工厂位于泰国东部经济走廊（EEC）核心区，占地 588 亩，规划总产能 20 万辆，2025 年 5 月建成一期 10 万辆产能，布局深蓝、启源等品牌的新能源汽车战略产品，主要供应泰国并辐射东南亚、欧洲、澳大利亚等全球右舵市场。

### 二、重点环节智能化建设情况

工厂以“绿色、智能”为核心目标，构建起“智能工厂一云一网一平台”的架构，建成 25 个核心数字化场景，覆盖工艺开发、生产作业、生产运营、物料配送等关键业务环节，建成了焊接、涂装、总装和电池等智能化车间，具备 EV、REEV、燃油车等跨平台柔性制造能力。

#### 1. 智能工厂总体架构

工厂构建全球统一的数字底座 2.0，实现云边协同、系统主数据贯通与数据统一。打造了国际化的制造数智化平台，围绕制造业务全要素，贯通业务与数据链路全链路，达成横向到边、纵向到底的系统融合。通过打通产品、订单、生产制造 3 大数据流，构筑计划管理、零部件物流、生产执行、质量管理及整车物流业务数字化应用，显著提升业务协同效率。同时，结合物联网等新

一代信息技术与智能装备，应用绿色工程、柔性制造、钢铝混合等先进工艺，建成了具备数据感知、高度自动化的智能工厂。

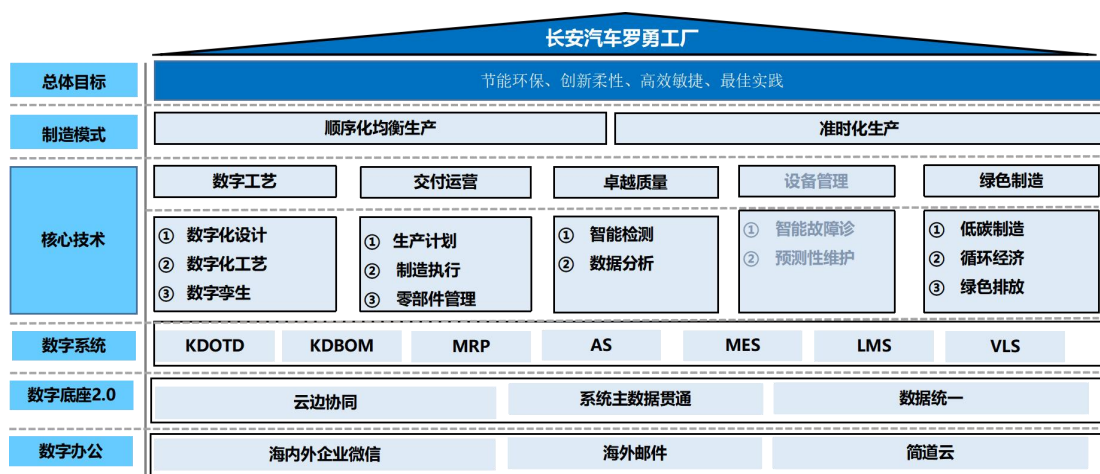


图 1 工厂总体架构图

## 2. 研发设计：基于数字孪生的工艺与工厂全流程虚拟仿真验证

通过工艺数字化设计与虚拟仿真深度融合，构建“全链路工艺验证+虚拟工厂运营”新模式。首先，基于与产品、供应商的3D协同在线设计，打通从工业设计到生产制造再到工艺验证与优化的全流程。在此基础上，建立统一的数字化设计与制造平台，集成工艺设计与管理、协同 workflows、企业资源和工艺知识、虚拟制造仿真及工艺文档管理等能力，支撑贯穿生产建设全过程的数字化仿真、虚拟制造以及工艺文件管理，显著提升生产线设计水平和验证效率。同时，工厂设计阶段整合建筑、车间、产线设备、物流及公用设施全要素信息，进行数字化验证。针对海外市场多样化的订单需求，在虚拟工厂中模拟顺序化制造过程，精准识别各类条件下可能出现的生产瓶颈。

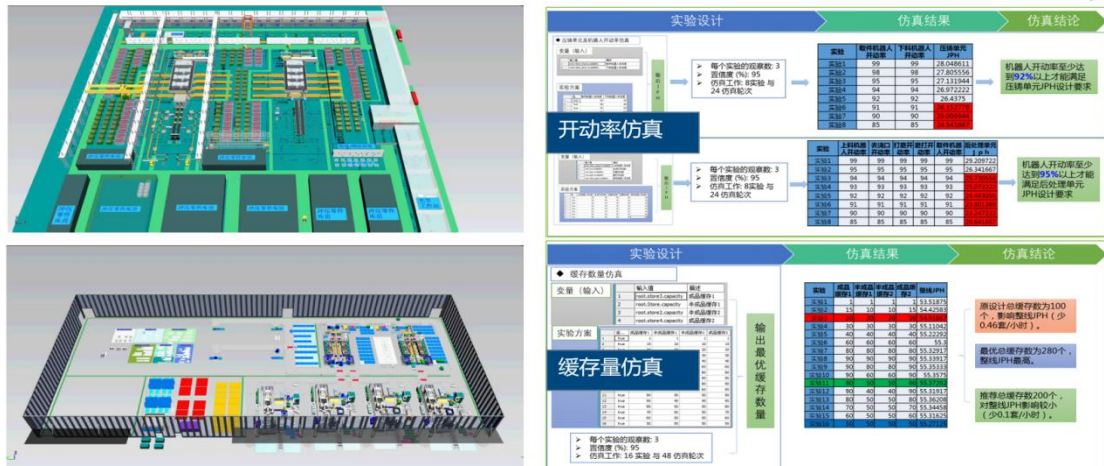


图2 工厂数字化设计及仿真

### 3. 生产制造：多车型柔性智能生产

工厂构建焊接、涂装、总装、电池等自动化生产线，搭载行业先进的工业控制与数字化管理系统，支持多车型、多机型的混线智能化生产。焊接车间采用 FDS、SPR、铝螺柱焊等钢铝连接工艺，自动化率 100%；总装车间应用 18 套全自动化及智能控制系统，满足多动力、多车型共线生产；电池车间采用智能算法调度 AGV，对产线各工位进行智能配送。此外，创建了“工业大脑”系统，基于先进的工业控制平台，可自动获取订单信息、生产计划及车型数据，对在制品实现全过程的自动跟踪，并自动完成车辆识别、跟踪及设备控制。同时，依托自主可控的物联网平台，实时采集现场数据，生成产线状态、设备故障、生产完成情况等信息，对生产人员和进度进行智能管控。



图 3 智能化装备

#### 4. 运营管理: 构建多业务统一的智能管理平台, 运营效率大幅提升

通过建立统一数字底座 2.0, 打通多源异构数据壁垒, 构建计划、订单、物流等能力中心, 推动运营管理实现从被动响应到主动协同的跃升, 运营效率和决策质量显著提升 20%, 系统实施周期缩短 20%。一是智能排程排产, 以满足销售需求为核心, 综合制造、工艺、供应链信息及排产策略, 指导制造执行并拉动资源; 二是制造管理, 基于制造体系搭建智能决策平台, 开发 25 类核心业务场景, 实现多维数据智能分析, 支撑管理层实时决策; 三是零部件管理, 对从国内外零部件供应商、国内包装中心、泰国报关、KD 仓管理、入场物流到上线等全链路进行业务赋能, 形成闭环监控与分级响应, 显著提升供应链韧性。



图 4 智能化驾驶舱

### 三、工厂实施成效

工厂打造了多平台高度柔性的混流生产线，大量采用国产装备及工业软件，关键设备数控率达 95%，关键设备联网率达 100%，设备综合利用率达 95%。项目上量周期短，单车工时（HPV）从初期的 36 降低至 29，一次下线合格率（FTT）从初期的 10%提升至 70%。工厂将数字化能力深度融合制造核心业务，依托统一数字化底座 2.0，实现全球全栈技术一致性。通过打通产品、订单、生产制造 3 大数据流，构建计划、订单、物流等能力中心，打造 30 个微服务，使运营效率提升 20%。

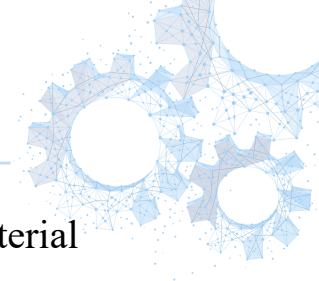
## **Thailand—Changan Automobile Vehicle Manufacturing Smart Factory**

### **I. Overview of the Overseas Factory**

The factory serves as Changan Automobile's overseas bridgehead in Southeast Asia under its "All Rivers Flow to the Sea" strategy. It is tasked with establishing Changan's overseas benchmark smart factory and stands as the overseas base with the largest planned production capacity and the highest level of intelligence. Located in the core area of Thailand's Eastern Economic Corridor (EEC), the factory covers an area of 588 rai, with a total planned capacity of 200,000 vehicles. The first phase, with an annual capacity of 100,000 vehicles, will be completed in May 2025. It will produce strategic new energy vehicle products under brands such as Deep Blue and Qiyuan, primarily supplying the Thai market while radiating to global right-hand drive markets including Southeast Asia, Europe, and Australia.

### **II. Status of Intelligent Construction in Key Areas**

With "green and intelligent" as its core objectives, the factory has established an architecture of "one cloud, one network, and one platform for the smart factory." It has built 25 core digital scenarios covering key business processes such as process development,



production operations, production management, and material distribution. The factory has also developed intelligent workshops for welding, painting, final assembly, and battery assembly, enabling flexible cross-platform manufacturing capabilities for EVs, REEVs, and conventional fuel vehicles.

## **1. Overall Architecture of the Smart Factory**

The factory has established a globally unified Digital Foundation 2.0, enabling cloud – edge collaboration, seamless integration of system master data, and unified data management. An international intelligent manufacturing digital platform has been developed, covering all elements of manufacturing operations and connecting end-to-end business and data links to achieve system integration horizontally across functions and vertically through all levels. By integrating three major data streams—product, order, and production—the factory has built digital applications for production planning, parts logistics, production execution, quality management, and finished vehicle logistics, significantly improving business collaboration efficiency. Furthermore, leveraging next-generation information technologies such as the Internet of Things, along with smart equipment and advanced processes including green engineering, flexible manufacturing, and steel-aluminum hybrid technologies, the factory

has become a smart factory featuring data perception and a high degree of automation.

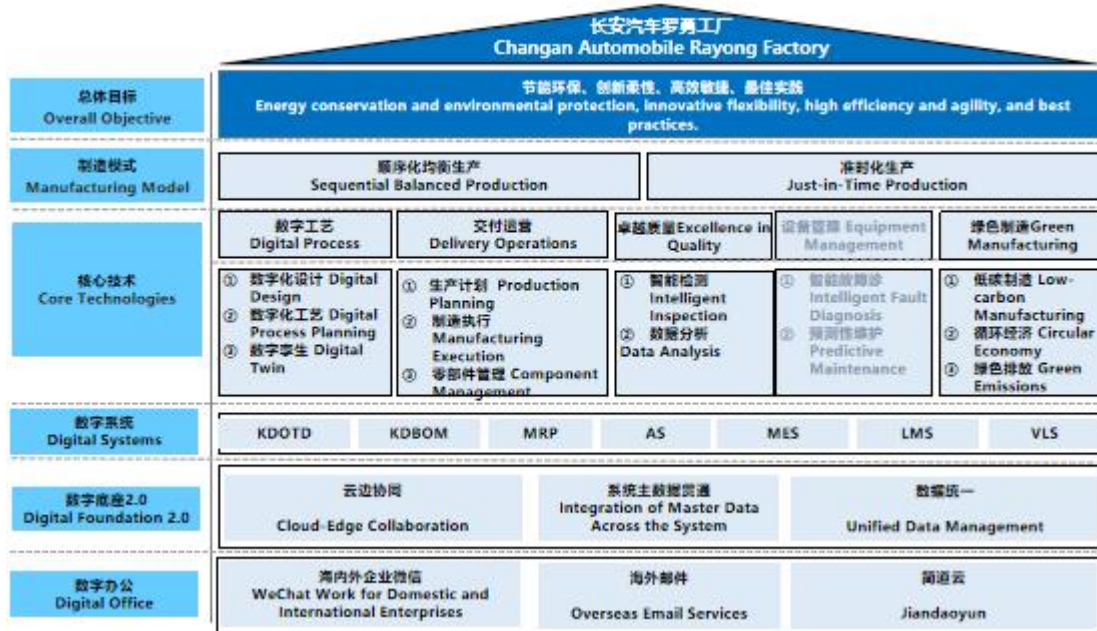


Figure 1: Overall Factory Architecture Diagram

## 2. Research & Development and Design: Full-Process Virtual Simulation Verification of Processes and Factory Based on Digital Twin

By deeply integrating digital process design with virtual simulation, a new model combining "end-to-end process verification + virtual factory operation" has been established. First, based on collaborative online 3D design with product teams and suppliers, the entire process from industrial design and manufacturing to process verification and optimization is connected. On this basis, a unified digital design and manufacturing platform has been developed, integrating capabilities



such as process design and management, collaborative workflows, enterprise resources and process knowledge, virtual manufacturing simulation, and process documentation management. This platform supports digital simulation, virtual manufacturing, and process document management throughout the entire production construction lifecycle, significantly improving the design quality of production lines and verification efficiency. In addition, during the factory design phase, all elements of building, workshop, production line equipment, logistics, and utilities are integrated for digital verification. To address diverse order requirements in overseas markets, the sequential manufacturing process is simulated in the virtual factory, enabling precise identification of potential production bottlenecks under various conditions.

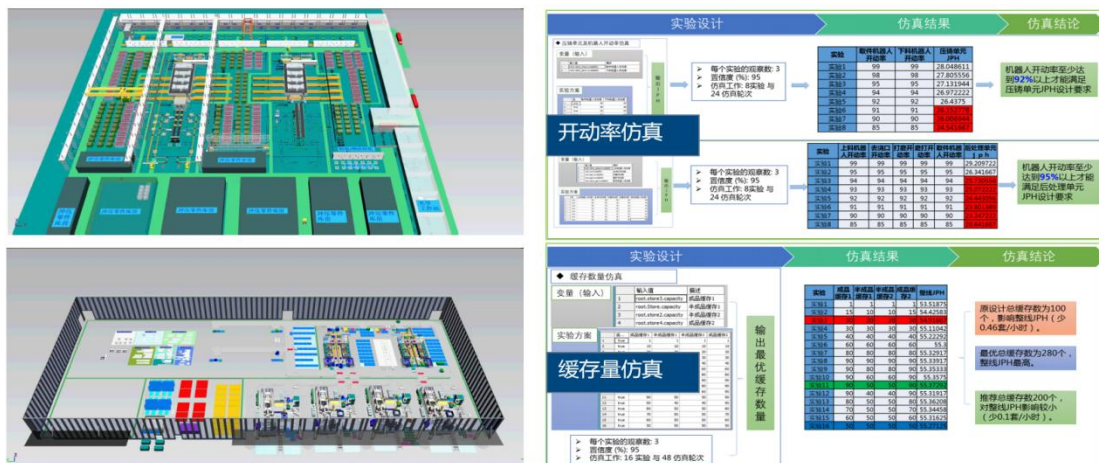


Figure 2: Factory Digital Design and Simulation

### 3. Production and Manufacturing: Flexible Smart Production for

## **Multiple Vehicle Models**

The factory has built automated production lines for welding, painting, final assembly, and battery assembly, equipped with industry-advanced industrial control and digital management systems to support mixed-line smart production of multiple vehicle and powertrain models. The welding workshop employs steel-aluminum joining technologies such as FDS, SPR, and aluminum stud welding, achieving a 100% automation rate. The final assembly workshop utilizes 18 fully automated and intelligent control systems to enable mixed-model production across multiple powertrain types and vehicle models. The battery workshop uses intelligent algorithms to dispatch AGVs for smart material delivery to each station along the production line. In addition, an "Industrial Brain" system has been developed. Based on an advanced industrial control platform, it automatically retrieves order information, production plans, and vehicle model data, enabling automatic tracking of work-in-progress throughout the entire process, as well as automatic vehicle identification, tracking, and equipment control. Meanwhile, relying on an independently controllable IoT platform, real-time field data is collected to generate information on line status, equipment failures, production completion, and more, enabling intelligent management and control of production personnel and progress.

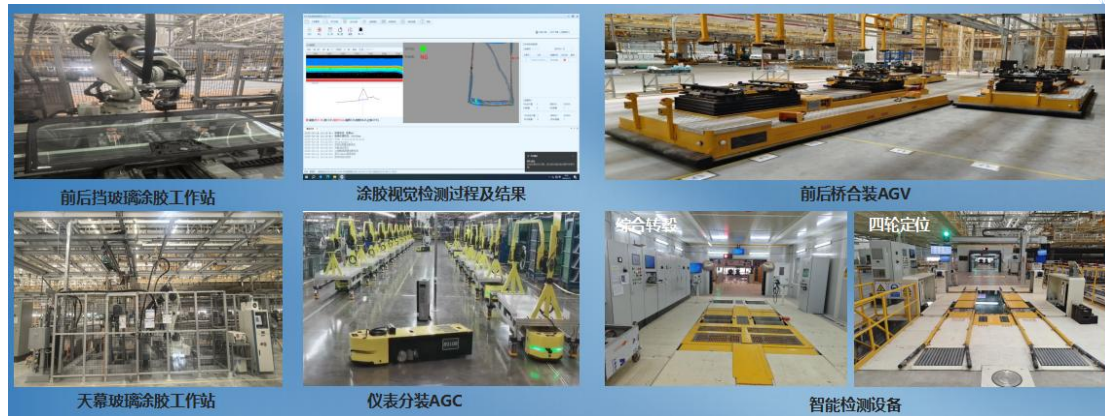


Figure 3: Intelligent Equipment

#### **4. Operations Management: Building a Multi-Business Unified Intelligent Management Platform to Significantly Improve Operational Efficiency**

By establishing a unified Digital Foundation 2.0, the factory has broken down barriers between multi-source heterogeneous data and built capability centers for planning, order management, logistics, and more. This has driven a leap in operations management from passive response to proactive collaboration, improving operational efficiency and decision-making quality by a significant 20%, and reducing system implementation cycle time by 20%.

First, intelligent scheduling and production planning — centered on meeting sales demand and integrating manufacturing, process, supply chain information, and scheduling strategies to guide manufacturing execution and pull resources. Second, manufacturing management — an intelligent decision-making platform has been built based on the

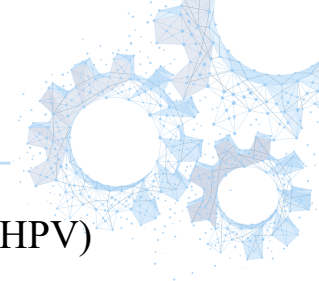
manufacturing system, developing 25 types of core business scenarios to enable multi-dimensional data analysis and support real-time decision-making by management. Third, parts management—end-to-end business empowerment is provided across the entire chain, from domestic and international parts suppliers, domestic packaging centers, Thai customs clearance, KD warehouse management, inbound logistics, to line-side delivery, forming closed-loop monitoring and tiered response mechanisms to significantly enhance supply chain resilience.



Figure 4: Intelligent Cockpit

### III. Implementation Effectiveness of the Overseas Factory

The factory has built a highly flexible mixed-flow production line supporting multiple platforms, extensively adopting domestically manufactured equipment and industrial software. The CNC rate of key equipment reaches 95%, the networking rate of key equipment reaches 100%, and the overall equipment effectiveness (OEE) reaches



95%. The project ramp-up cycle is short, with hours per vehicle (HPV) reduced from an initial 36 to 29, and first-time throughput (FTT) increased from an initial 10% to 70%. The factory deeply integrates digital capabilities into core manufacturing operations, relying on a unified Digital Foundation 2.0 to achieve global full-stack technology consistency. By connecting three major data streams—product, order, and production—the factory has established capability centers for planning, order management, logistics, and more, and developed 30 microservices, resulting in a 20% improvement in operational efficiency.

## 泰国——海尔空调智能工厂

### 一、海外工厂整体情况

工厂位于泰国东部经济走廊 WHA 东海岸工业园三期，是海尔集团全球化制造体系的重要节点，于 2024 年奠基，2025 年投产，占地 486 亩，已建成窗式空调、分体式空调生产车间及大型仓储中心，年产能达 600 万套，带动当地超 3000 人就业。工厂以家用空调为核心，持续拓展窗式空调、分体式空调、除湿机、移动空调及房车空调等多元化产品矩阵，并依托海尔、GE、AQUA 等多品牌协同发展，形成差异化竞争优势。

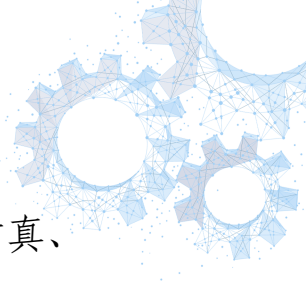
凭借雄厚的技术实力、全球资源整合能力及品牌影响力，公司已发展成为东南亚家电行业的重要参与者，海外市场竞争力与品牌认知度持续增强，2025 年作为中国企业对外投资优秀案例获《人民日报》报道，2026 年入围 Gartner 专业力量年度供应链大奖，成为本年度家电行业唯一获此殊荣的企业。

### 二、重点环节智能化建设情况

筑牢产品从设计到售后全链路竞争力的智能技术基础，打造海尔集团海外首个打通“订单-生产-物流-售后”全流程业务的标杆工厂。

#### 1. 工厂架构：全域互联的数字化业务应用架构

工厂架构自下而上涵盖设备层、物联层、执行层、中台能力及前台触点。底层通过 SCADA、边缘网关等实现钣金、注塑等



设备的数据采集与控制；执行层依托各类MES系统、工业仿真、SPC质量控制系统落实生产作业；中台聚焦产销协同、物料保障、精益生产及成品发运四大核心业务流，集成SAP、APS、WMS等系统支撑高效运营，并辅以设备、模具、能源及安全等生产保障模块；顶层则通过Hwork大屏及工作站等前台触点，实现从订单、成本到物流、质量的全方位可视化与运营管理，构建起端到端的智能制造闭环体系。

工厂数字化应用架构

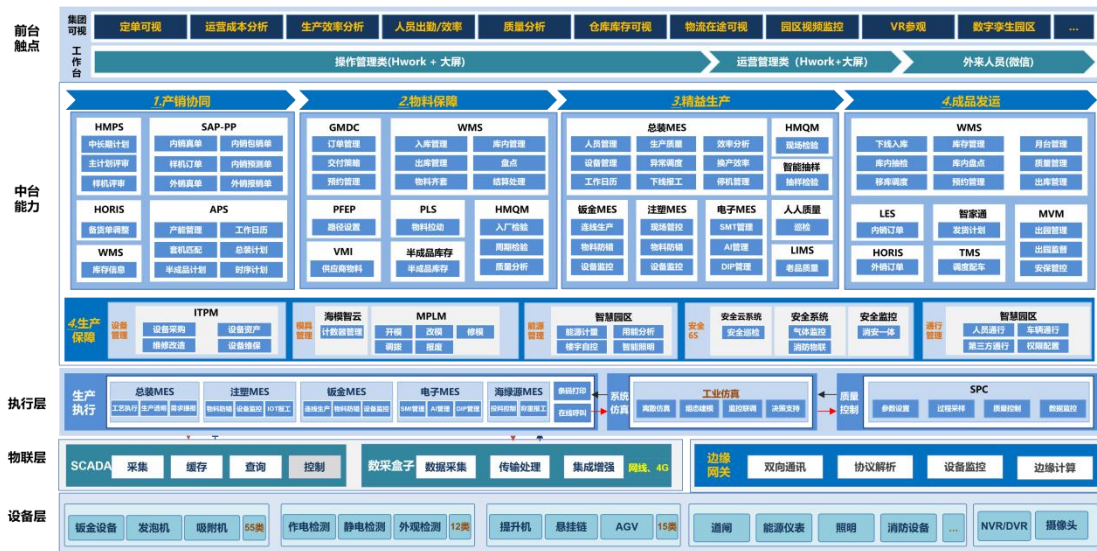


图 1 工厂数字化应用架构

2. 研发设计：虚实结合的一体化敏捷研发平台

依托海尔集团研发一体化平台能力、人员支持、技术集群，通过国内全流程智能化研发设计体系实现了国内外研发协同设计，大幅提升研发效率与产品竞争力。

数据驱动创新层面，打通全球不同区域（亚热带、温带、寒带）及不同工况的用户数据，借助智能算法，实现跨地域、跨气候、跨用户使用习惯的多维度数据分类与精准分析，推动需求收

集方式从传统人工调研升级为 AI 驱动的精准挖掘，形成“数据采集 - 智能分析 - 需求洞察 - 产品优化”的闭环体系，大幅提升产品设计的用户匹配度与迭代效率。协同设计方面，搭建全球化研发平台与知识库，实现全球研发资源及核心供应商的在线协同，通过标准化零部件库，确保新产品优先调用成熟模块，同时结合几何相似性检索技术，赋能设计人员快速检索历史数据，显著提高设计复用效率。

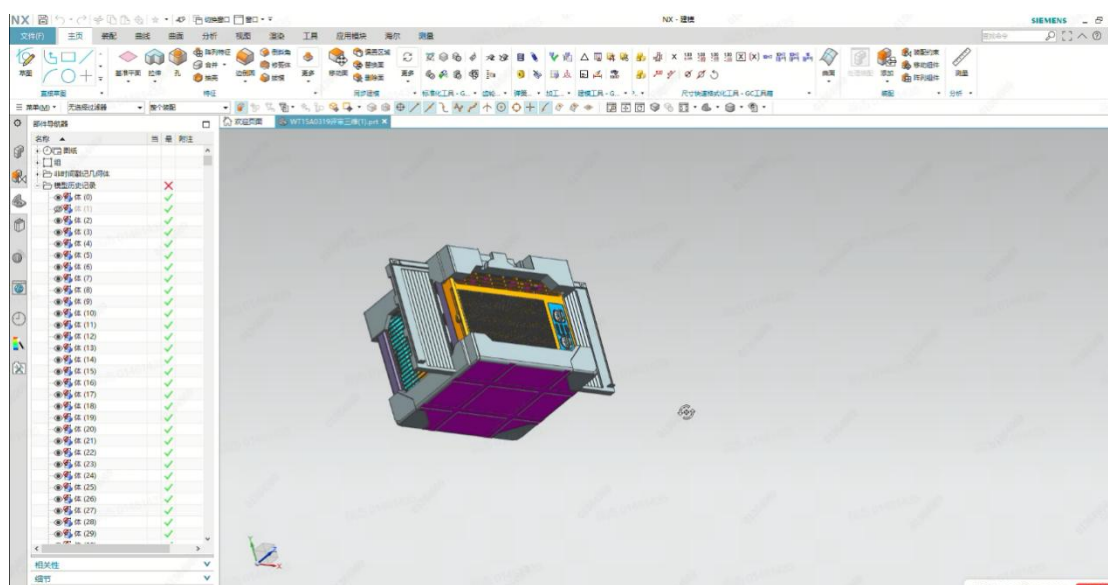
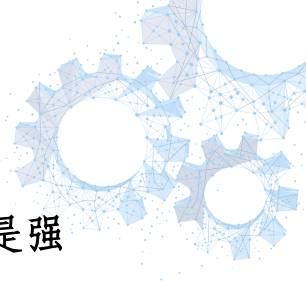


图 2 研发一体化平台

### 3. 生产制造：柔性智能的全场景生产执行管理

立足全域智能制造布局，作业端实现柔性生产、智能质检与设备智慧运维，保障制造节奏；管理端优化智能排产、智慧物流，统筹安全能源管控，全面提质增效。

生产作业方面，一是打造柔性生产能力，应用先进过程控制、工艺动态优化等技术，部署工艺参数智能预测与智能调度系统，接入喷粉前处理、焊接、抽空灌注等关键工序参数，动态调整运



行参数、物料配比和工艺调度路径，精准适配生产需求。二是**强化智能作业与质量管控**，依托工业机器人、协作机器人等智能装备，实现危险作业无人化与人机协同高效作业，结合深度学习驱动的智能外观视觉检测系统，以及基于 AI 声音振动的空调异响检测系统，实现生产线全量产品自动质检，精准识别与溯源空调运行异响，全方位保障生产稳定性；三是**优化设备运维管理**，部署基于 AI 时序预测的设备预测维护系统，运用知识图谱、振动分析等技术，实现空调高速冲床、注塑机等关键设备健康状态预警与维护任务精准触发，减少非计划停机，提升设备综合利用率。

生产管理方面，一是**打通全链路生产管控**，打造混合整数规划（MIP）与遗传算法（GA）相结合的多目标优化排产引擎，依托生产计划、智能排产、动态调度等系统，融合需求预测、运筹优化、强化学习等技术，实现生产计划动态调整、制造资源高效配置，有效缩短订单交付周期；二是**完善仓储物流智能化**，建成以 HGWMS、WMS、TMS 及 GIMS 四个系统为底座、“立体库 + AGV”为协同支撑的全流程物流管理体系，实现仓储作业全流程精细化管理，以及运输作业全流程可视化管控、进口原材料端到端管控。三是**强化综合管控能力**，构建安全一体化管控、能源智能管控及碳资产全生命周期管理系统，打造聚焦注塑、钣金、焊接、制冷测试等高能耗工序的 AI 智能调度与高能耗工序节能优化系统，覆盖电、气、水、压缩空气、光伏绿能等多介质 AI 能源智控方案，筑牢生产安全防线、实现节能减排与低碳发展。



图 3 AI 在线质检系统

#### 4. 运营管理：多维互联的全流程高效运营体系

融合大数据、云计算、数字孪生等技术，实现经营决策科学高效、生产管理精准精益，产品远程运维、客户主动服务，供应链数字化管控、采购优化、风险预警及智能配送。全方位提升运营效率、降低成本，彰显智慧工厂核心竞争力。

一是经营决策智能化，搭建全园区高精度数字孪生平台，构建“感知—协议—支撑—管控—呈现”五层架构，实现工厂全维度实时映射，生产、设备、能源、安防等全场景可视管理，实现数据融合、流程协同、智能管控与科学决策；二是面向客户的主动服务，部署面向全球用户的产品预测性维护系统及主动服务模式，提前预警产品故障，自动匹配备件库存与维修指导方案，主动联系用户上门维修，相比传统报修模式，可大幅降低市场投诉及售后成本，增强用户粘性，实现可持续运营。三是供应链数字

化管控，拉通多系统的全球供应链运营体系，实现从客户下单、生产备货、物流配送、报关出运到财务结汇全流程管控，完成业务、生产、物流、关务、财务等核心数据的全面透视，支持全流程任务拆解、进度追踪与审批留痕，有效促进了跨部门协作。



图 4 全厂数字孪生运营管理平台

### 三、工厂实施成效

工厂依托全流程智能化，成为海外首个打通“订单 - 生产 - 物流 - 售后”全流程业务的标杆工厂。一是智能化改造成效显著，产品不良率下降 30%，产线平衡率与设备综合效率（OEE）均提升 15%，生产效率提升 35%；制造费率下降 30%，订单响应速度提升 50%，送料效率提升 30%。二是构建全价值链智能化体系，通过云端大模型与强化学习挖掘用户需求、驱动产品迭代，依托智能排产引擎、3D 视觉机器人、AGV 自动调度及设备故障预测技术实现高效自动化生产，通过集成大模型的 Hwork 平台完成智能订单处理，以多模态 AI 质检与 AI 光储一体化能源管理保障

品质与绿色生产。三是形成强示范复制效应，沉淀出覆盖生产制造、质量追溯、市场运营、采购计划协同等 13 个领域的智能制造样板，已在海外 10 余家工厂推广复制，推动整体产业向智能化、高效化与低碳化转型。



## **Thailand—Haier Air Conditioner Smart Factory**

### **I. Overview of the Overseas Factory**

Located in Phase III of the WHA Eastern Seaboard Industrial Estate in Thailand's Eastern Economic Corridor, the factory serves as an important node in Haier Group's global manufacturing system. Groundbreaking took place in 2024, and production commenced in 2025. The factory covers an area of 486 rai and has built production workshops for window air conditioners and split-type air conditioners, along with a large-scale warehousing center, achieving an annual production capacity of 6 million units and creating over 3,000 local jobs. With household air conditioners as its core, the factory continues to expand its diversified product portfolio, including window air conditioners, split-type air conditioners, dehumidifiers, portable air conditioners, and RV air conditioners. Leveraging the synergistic development of multiple brands such as Haier, GE, and AQUA, the factory has formed a differentiated competitive advantage.

Backed by strong technical capabilities, global resource integration strength, and brand influence, the company has grown into a key player in the Southeast Asian home appliance industry, with continuously enhanced overseas market competitiveness and brand

recognition. In 2025, it was featured by People's Daily as an outstanding case of Chinese corporate overseas investment. In 2026, it was shortlisted for Gartner's Powerhouse of the Professional Supply Chain of the Year Award, becoming the only home appliance company to receive this honor that year.

## **II. Status of Intelligent Construction in Key Areas**

The factory has established a solid smart technology foundation to support end-to-end competitiveness across the entire product lifecycle, from design to after-sales service. It has become Haier Group's first overseas benchmark factory that integrates the full-process business of "order - production - logistics - after-sales."

### **1. Factory Architecture: Fully Interconnected Digital Business Application Architecture**

The factory architecture covers, from bottom to top, the equipment layer, IoT layer, execution layer, platform capabilities, and front-end touchpoints. At the bottom layer, data acquisition and control for equipment such as sheet metal and injection molding machines are achieved through SCADA, edge gateways, etc. The execution layer relies on various MES systems, industrial simulation, and SPC quality control systems to carry out production operations. The platform layer



focuses on four core business flows: production-sales coordination, material support, lean manufacturing, and finished product shipment. It integrates systems such as SAP, APS, and WMS to support efficient operations, supplemented by production support modules for equipment, molds, energy, and safety. At the top layer, front-end touchpoints such as Hwork dashboards and workstations enable comprehensive visualization and operational management across orders, costs, logistics, and quality, forming an end-to-end closed-loop system for intelligent manufacturing.

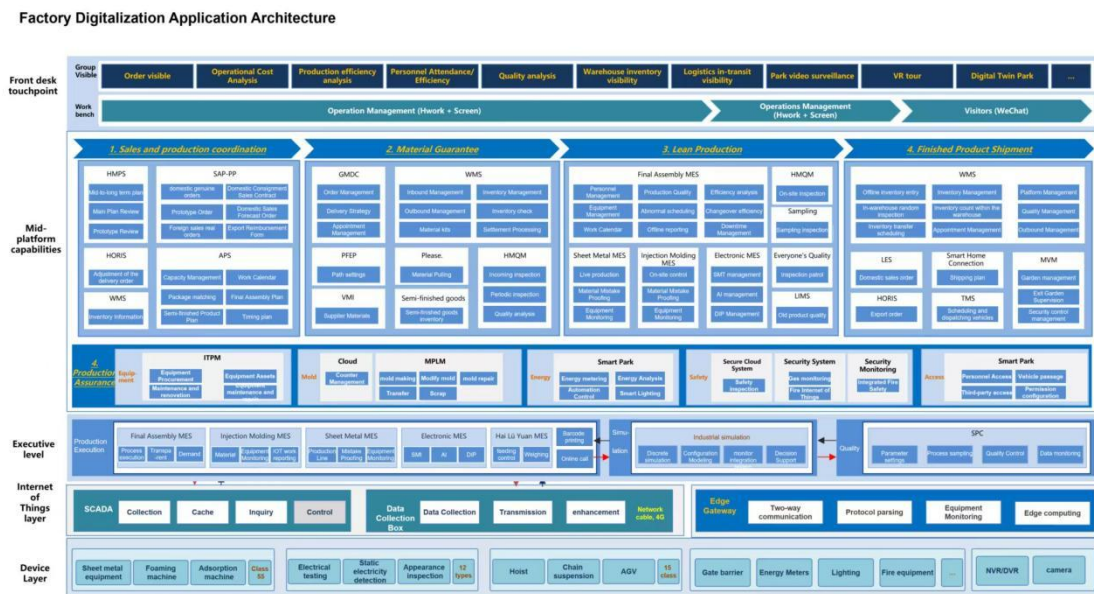


Figure 1: Factory Digital Application Architecture

## 2. Research & Development and Design: Integrated Agile R&D Platform Combining Virtual and Physical Approaches

Leveraging Haier Group's integrated R&D platform capabilities, personnel support, and technology clusters, the factory enables

collaborative R&D between domestic and overseas teams through a full-process intelligent R&D and design system, significantly improving R&D efficiency and product competitiveness.

At the level of data-driven innovation, user data from different global regions (subtropical, temperate, and frigid zones) and various operating conditions is integrated. Using intelligent algorithms, multi-dimensional data classification and precise analysis across regions, climates, and user habits are achieved, upgrading the method of demand collection from traditional manual research to AI-driven precise mining. This forms a closed-loop system of "data collection - intelligent analysis - demand insight - product optimization," greatly enhancing product design's user alignment and iteration efficiency. In terms of collaborative design, a global R&D platform and knowledge base have been established to enable online collaboration among global R&D resources and core suppliers. Through a standardized parts library, new products are prioritized to call upon mature modules, while geometric similarity search technology empowers designers to quickly retrieve historical data, significantly improving design reuse efficiency.

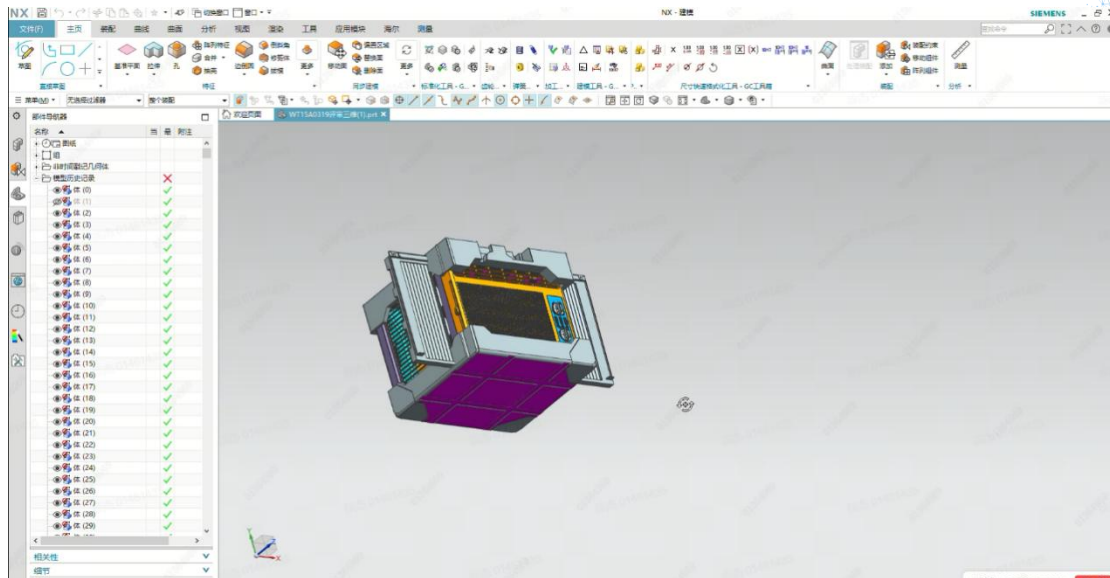


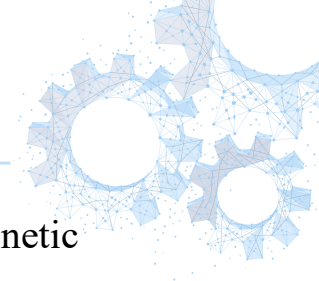
Figure 2: Integrated R&amp;D Platform

### 3. Production and Manufacturing: Flexible and Intelligent Full-Scenario Production Execution Management

Based on a globally oriented intelligent manufacturing layout, in production operations, flexible production, intelligent quality inspection, and smart equipment maintenance are achieved to ensure manufacturing rhythm. First, flexible production capabilities are developed by applying advanced process control and dynamic process optimization technologies. An intelligent parameter prediction and smart scheduling system is deployed, accessing key process parameters such as powder coating pretreatment, welding, and vacuum-pulling & refrigerant charging, to dynamically adjust operating parameters, material ratios, and process scheduling paths, precisely adapting to production demands. Second, intelligent

operations and quality control are strengthened by leveraging smart equipment such as industrial robots and collaborative robots to achieve unmanned operation of hazardous tasks and efficient human-robot collaboration. Combined with a deep learning-driven intelligent appearance visual inspection system and an AI-based sound and vibration detection system for abnormal air conditioner noise, fully automatic quality inspection of all products on the production line is achieved, enabling precise identification and traceability of abnormal operating noises in air conditioners and ensuring comprehensive production stability. Third, equipment operation and maintenance management is optimized by deploying an AI time-series prediction-based predictive maintenance system. Using technologies such as knowledge graphs and vibration analysis, the system provides health status warnings and precisely triggers maintenance tasks for key equipment such as high-speed air conditioner punch presses and injection molding machines, reducing unplanned downtime and improving overall equipment effectiveness.

In production management, intelligent production scheduling and smart logistics are optimized, while safety and energy management are coordinated to comprehensively improve quality and efficiency. First, end-to-end production management and control is achieved by developing a multi-objective optimized production scheduling engine



combining Mixed Integer Programming (MIP) and Genetic Algorithms (GA). Relying on systems for production planning, intelligent scheduling, and dynamic scheduling, and integrating technologies such as demand forecasting, operations research optimization, and reinforcement learning, dynamic adjustment of production plans and efficient allocation of manufacturing resources are realized, effectively shortening order delivery cycles. Second, warehousing and logistics intelligence is enhanced by establishing a full-process logistics management system underpinned by four systems—HGWMS, WMS, TMS, and GIMS—and supported by the synergy of "automated warehouses + AGVs." This enables refined management of the entire warehousing process, visualized control of the entire transportation process, and end-to-end management of imported raw materials. Third, comprehensive management capabilities are strengthened by building an integrated safety management system, intelligent energy management and control system, and a full-lifecycle carbon asset management system. An AI-powered smart scheduling and energy-saving optimization system is developed focusing on high-energy-consumption processes such as injection molding, sheet metal fabrication, welding, and refrigeration testing. Multi-media AI-driven energy management solutions covering electricity, gas, water, compressed air, photovoltaic green

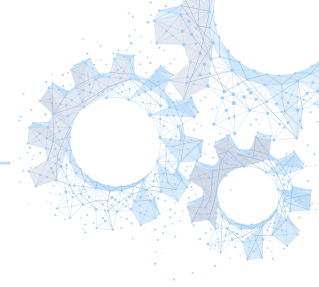
energy, and more are implemented, ensuring production safety, achieving energy savings and emission reductions, and promoting low-carbon development.



Figure 3: AI Online Inspection System

#### 4. Operations Management: Multi-Dimensionally Connected, Full-Process Efficient Operations System

Integrating technologies such as big data, cloud computing, and digital twins, in operations management, scientific and efficient business decision-making, precise and lean production management, remote product maintenance and proactive customer service, as well as digital supply chain control, procurement optimization, risk warning, and smart distribution are achieved. This comprehensively improves operational efficiency, reduces costs, and demonstrates the



core competitiveness of the smart factory.

First, intelligent business decision-making is realized by building a high-precision digital twin platform for the entire campus, with a five-layer architecture of "perception - protocol - support - control - presentation." This enables real-time mapping of the entire factory across all dimensions, visualized management of all scenarios including production, equipment, energy, and security, and achieves data integration, process collaboration, intelligent control, and scientific decision-making. Second, customer-oriented proactive services are delivered by deploying a predictive maintenance system for global users and a proactive service model. The system provides early warnings of product failures, automatically matches spare parts inventory with repair guidance, and proactively contacts users to schedule on-site repairs. Compared with traditional repair request models, this significantly reduces market complaints and after-sales costs, enhances user loyalty, and enables sustainable operations. Third, digital supply chain control is achieved by streamlining a multi-system global supply chain operations system. This enables end-to-end control from customer order placement, production preparation, logistics distribution, customs clearance and shipment, to financial settlement. A comprehensive view of core data across business, production, logistics, customs, and finance is achieved, supporting

full-process task decomposition, progress tracking, and approval traceability, effectively promoting cross-departmental collaboration.



Figure 4: factory-Wide Digital Twin Operations Management Platform

### III. Implementation Effectiveness of the Overseas Factory

Leveraging full-process intelligent technologies, the factory has become the first overseas benchmark factory to integrate the full-process business of "order - production - logistics - after-sales." First, significant results have been achieved in intelligent transformation: product defect rate decreased by 30%, production line balance rate and overall equipment effectiveness (OEE) both increased by 15%, and production efficiency improved by 35%; manufacturing cost rate decreased by 30%, order response speed increased by 50%, and material feeding efficiency improved by 30%.



Second, a full-value-chain intelligent system has been established: cloud-based large models and reinforcement learning are used to mine user needs and drive product iteration; intelligent scheduling engines, 3D vision robots, AGV automatic dispatching, and equipment fault prediction technologies enable efficient automated production; the Hwork platform integrated with large models handles intelligent order processing; and multimodal AI quality inspection alongside AI-integrated photovoltaic and energy storage management systems ensure quality and green production. Third, a strong demonstration and replication effect has been formed: intelligent manufacturing benchmarks covering 13 areas—including production manufacturing, quality traceability, market operations, and procurement planning collaboration—have been developed and replicated across more than 10 overseas factories, driving the overall industry's transformation toward intelligence, efficiency, and low-carbon development.

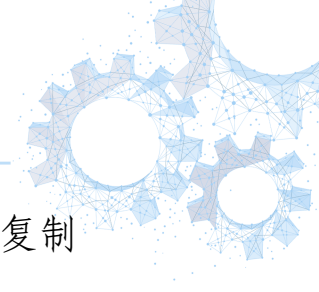
## 泰国——中策高性能子午胎智能工厂

### 一、海外工厂整体概况

工厂选址泰国罗勇府泰中罗勇工业园，是中策橡胶集团全球化战略布局的核心落地载体，也是国内轮胎产业在东南亚布局的标杆级智能化制造基地，纳入中泰共建“一带一路”重点制造业合作示范项目。工厂2014年启动基建施工，2016年正式投产运营，总投资290亿泰铢，总占地面积58.4万平方米。主营高性能半钢、全钢子午胎及工程胎、摩托胎、实心胎等全系列产品的研发制造与全球营销布局，设计年产能达3400万条以上，年营收约10亿美元，年消耗天然橡胶17万吨，产品辐射全球88个国家和地区。凭借过硬的产品品质，工厂高端子午胎成功切入福特、斯特兰蒂斯等国际主流车企、大型物流集团核心供应链，有效带动泰国本地就业、配套产业集聚与产业链能级提升，持续增强中国轮胎产业的全球品牌影响力与行业话语权。

### 二、重点领域智能化建设情况

工厂锚定“打造泰国轮胎行业海外智能工厂示范标杆”总体目标，恪守精益管控、绿色低碳、数字赋能发展理念，深度融合工业互联网、人工智能、大数据、数字孪生等新一代信息技术，纵向打通OT生产控制层与IT业务管理层数据链路，横向贯通市场需求、研发设计、采购配套、智能生产、质量检测、智能仓储、物流交付、能源管控、经营决策等全业务链，构建端到端精



益数字化运营体系，形成适配泰国属地规则、协同高效、可复制推广的海外智能工厂运营新模式。

### 1. 智能工厂总体架构

工厂依托“1+N”工业互联网平台总体架构筑牢数字底座，统筹推进6大数字化转型领域、38项重点建设任务，实现全价值链数字化管控模式在泰国属地的创新落地与实践应用。以企业自研DMP数字化运营平台为核心枢纽，全面整合PLM、MES、ERP、WMS、QMS等核心业务系统，搭建统一集约的业务运营中台。梳理沉淀12条属地化专属业务流程、86项标准化核心业务流程，搭建一体化流程协同门户，整体运营综合效率提升42%以上，实现全业务端到端闭环管控，支撑集团总部与海外工厂跨国高效协同。



图1 “1+N”工业互联网平台

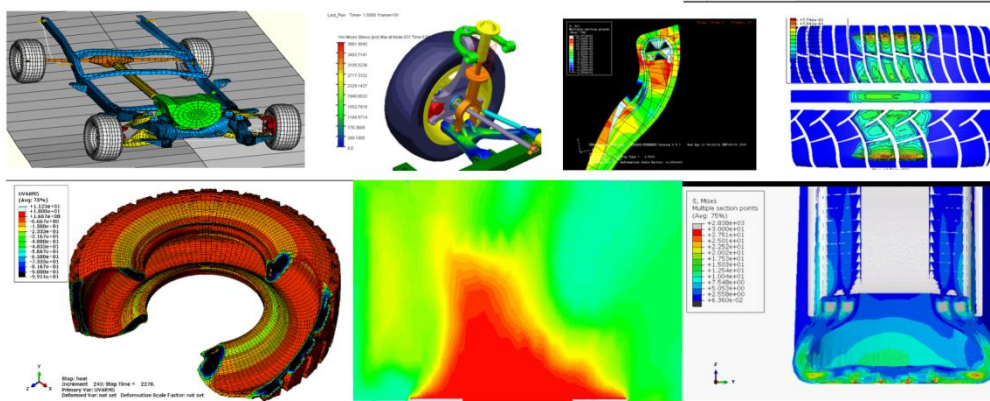


图 2 轮胎仿真测试

## 2. 生产制造：产线智能升级 系统协同管控提效

针对子午胎的炼胶、压延、裁断、成型、硫化、后整理全生产工序，工厂构建起全流程自动化、数字化、智能化一体化制造体系。**硬件层面**，全面部署智能成套装备与自动化产线：压延工序搭载智能调控单元，动态优化物料配比与生产节拍匹配；成型工序规模化应用机器人工作站，融合激光检测、3D 视觉定位技术，保障产品成型精度稳定；硫化工序配置伺服智能控制系统，实现关键工艺参数实时监控、生产链路全程溯源、异常工况自动告警，工厂核心工序数控化率达 92%，关键设备联网率 95%，智能制造硬件底座全面筑牢。**软件层面**，多套智能业务系统深度融合落地：MES 系统实时采集现场工况，实现智能排产、工序防错、生产进度动态调度；IoT 平台接入 680 台核心生产设备，对设备运行与能耗工况进行 7×24 小时在线监测；QMS 搭建全生命周期质量管控体系，通过 AI 算法实现质量风险前置预判与现场缺陷在线拦截；WMS 智能仓储实现备品备件集约化统筹管理，备件周转效率提升 65%。

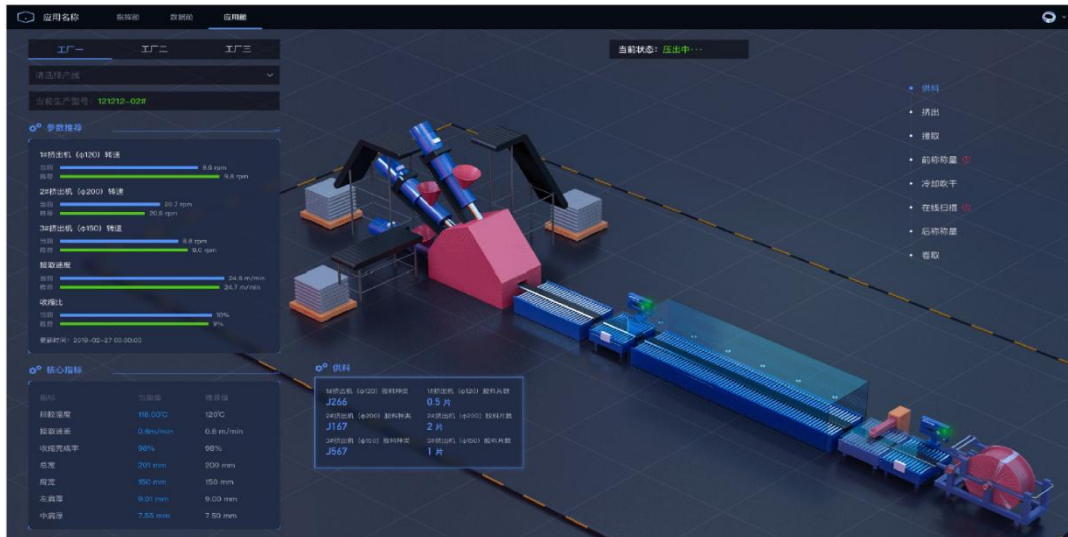


图 3 智能化数字压出线孪生体

### 3. 运营管理：数字运营提效 仓储能碳决策一体化支撑

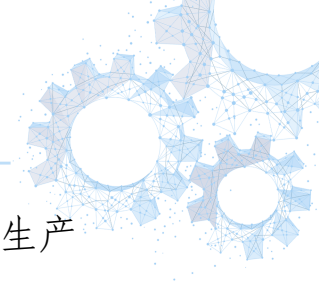
以 ERP 系统为核心，打通从客户订单到成品交付的全流程链路，保障跨国业务高效平稳运行，构建全球化供应链多级预警机制，建立风险识别、实时监测、分级响应、闭环处置管理体系，提升供应链保障与适应能力。**物流仓储方面**，采用智能立体仓库+EMS 无人输送模式，仓储空间利用率提升 200%，年均节约仓储运营成本超 4000 万元。**能源管控方面**，搭建智慧能碳双控管理平台，覆盖水、电、蒸汽、压缩空气、氮气等多能源介质，共 1322 个采集点位，实现能耗实时监测、结构分析与节能策略智能优化。**智能决策方面**，打造全价值链运营可视化驾驶舱，汇聚生产、质量、能耗、经营多维度数据，实现企业级关键 KPI 的动态监测与智能分析，同时支持跨部门及部门内部常规数据分析，辅助经营决策。



图 4 智能能碳管控平台

### 三、工厂实施成效

通过全链路数字化、智能化、绿色化升级建设，工厂在运营效率、生产成本、质量管控、供应链保障、绿色低碳方面取得成效。一是实现多维度提质增效，整体生产效率提升 42%，人均产出实现翻倍，产品不良率由 1.2% 降至 0.5%，胎胚成型一次合格率达 99.2%，单胎综合制造成本下降 18%，年度综合降本超 1.2 亿泰铢，备件采购周期缩短 55%，海外本地化配套率达 75%，单位产值综合能耗下降 18%，年节电 2800 万千瓦时，年减碳 2.8 万吨。二是构建了轮胎行业海外全价值链数字化标杆范式，完成集团成熟管理经验泰国本地化适配，打通研发、生产、供销、服务全业务域数字化链路，实现 12 大类子午胎混线生产，适配全球市场多品类、小批量、短交期需求。三是打造了智能制造与绿色低碳融合发展示范基地，深度融合智能管控与节能降碳，依托能

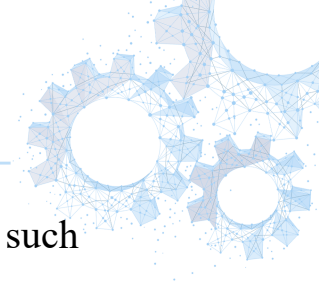


碳双控、分布式光伏、废水循环利用等举措，构建低碳循环生产模式，成为中泰产能合作及“一带一路”高质量发展标志性项目。

## **Thailand—Zhongce High-performance Radial Tire Smart Factory**

### **I. Overview of the Overseas Factory**

The factory is located in the Thai-Chinese Rayong Industrial Zone, Rayong Province, Thailand. It serves as the core implementation vehicle for Zhongce Rubber Group's global strategic layout and stands as a benchmark-level intelligent manufacturing base for China's tire industry in Southeast Asia. It has been designated as a key manufacturing cooperation demonstration project under the China-Thailand Belt and Road Initiative. Construction of the factory began in 2014, and it officially commenced operations in 2016, with a total investment of 29 billion Thai baht and covering an area of 584,000 square meters. The factory is primarily engaged in the R&D, manufacturing, and global marketing of a full range of products, including high-performance semi-steel radial tires, all-steel radial tires, engineering tires, motorcycle tires, and solid tires. Its designed annual production capacity exceeds 34 million units, with an annual revenue of approximately 1 billion US dollars and an annual consumption of 170,000 tons of natural rubber. Its products reach 88 countries and regions worldwide. Backed by excellent product quality, the factory's high-end radial tires have successfully entered the core



supply chains of major international automotive manufacturers such as Ford and Stellantis, as well as large logistics groups. The factory has effectively driven local employment in Thailand, fostered the agglomeration of supporting industries, and elevated the industrial chain, continuously enhancing the global brand influence and industry voice of China's tire industry.

## **II. Status of Intelligent Construction in Key Areas**

With the overarching goal of "establishing a benchmark overseas smart factory in the Thai tire industry," the factory adheres to the development principles of lean management, green and low-carbon operations, and digital empowerment. It deeply integrates next-generation information technologies such as the Industrial Internet of Things, artificial intelligence, big data, and digital twins. Vertically, it connects data links between the OT production control layer and the IT business management layer. Horizontally, it integrates the entire business chain, including market demand, R&D and design, procurement and supply, intelligent production, quality inspection, intelligent warehousing, logistics delivery, energy management, and business decision-making. An end-to-end lean digital operations system has been established, forming a new, replicable, and scalable

overseas smart factory operation model that adapts to local Thai regulations and is collaborative and efficient.

## **1. Overall Architecture of the Smart Factory**

The factory builds its digital foundation upon a "1+N" Industrial Internet platform architecture, systematically advancing 6 major digital transformation domains and 38 key construction tasks, thereby achieving the innovative implementation and practical application of a full-value-chain digital management and control model in Thailand. With the enterprise's self-developed DMP digital operation platform as the core hub, the factory fully integrates core business systems such as PLM, MES, ERP, WMS, and QMS to establish a unified and centralized business operations platform. By refining 12 localized proprietary business processes and 86 standardized core business processes, an integrated process collaboration portal has been built, improving overall operational efficiency by more than 42%. This enables end-to-end closed-loop management and control across all business operations, supporting efficient cross-border collaboration between the group headquarters and the overseas factory.



Figure 1: "1+N" Industrial Internet Platform

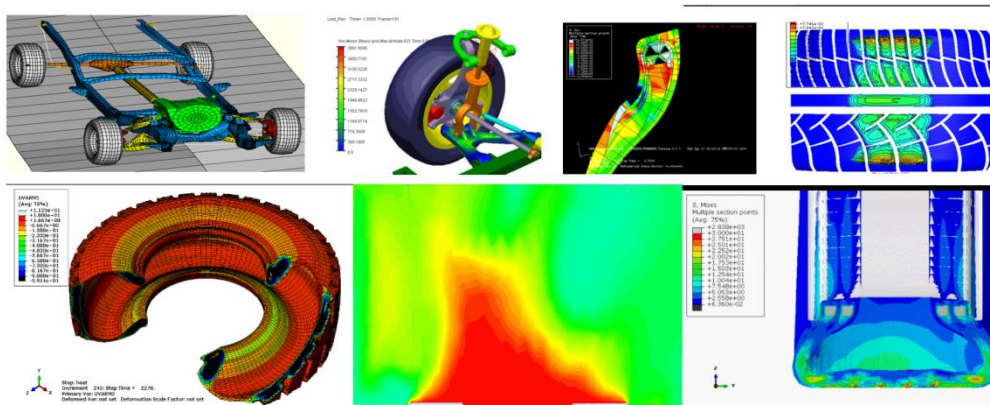


Figure 2: Tire Simulation Testing

## 2. Production and Manufacturing: Production Line Intelligent Upgrading and System Collaborative Control for Efficiency Improvement

For the entire production process of radial tires — including mixing, calendaring, cutting, building, curing, and post-finishing — the factory has established an integrated manufacturing system combining full-process automation, digitalization, and intelligence. On the hardware front, Complete Set of Intelligent Equipment and automated

production lines have been fully deployed: the calendaring process is equipped with intelligent control units that dynamically optimize material ratios and production rhythm matching; the building process utilizes robotic workstations on a large scale, integrating laser detection and 3D vision positioning technologies to ensure stable product building accuracy; the curing process is equipped with a servo intelligent control system, enabling real-time monitoring of key process parameters, full-traceability of the production chain, and automatic alarms for abnormal conditions. The CNC rate for core processes reaches 92%, and the networking rate for key equipment reaches 95%, laying a solid hardware foundation for intelligent manufacturing. On the software front, multiple intelligent business systems have been deeply integrated and implemented: the MES system collects real-time shop floor data to enable intelligent production scheduling, process error-proofing, and dynamic adjustment of production progress; the IoT platform connects 680 pieces of core production equipment, providing 24/7 online monitoring of equipment operation and energy consumption; the QMS establishes a full-lifecycle quality management and control system, using AI algorithms to achieve proactive quality risk prediction and online defect interception on the shop floor; the WMS intelligent warehousing system enables centralized and coordinated

management of spare parts, improving parts turnover efficiency by 65%.

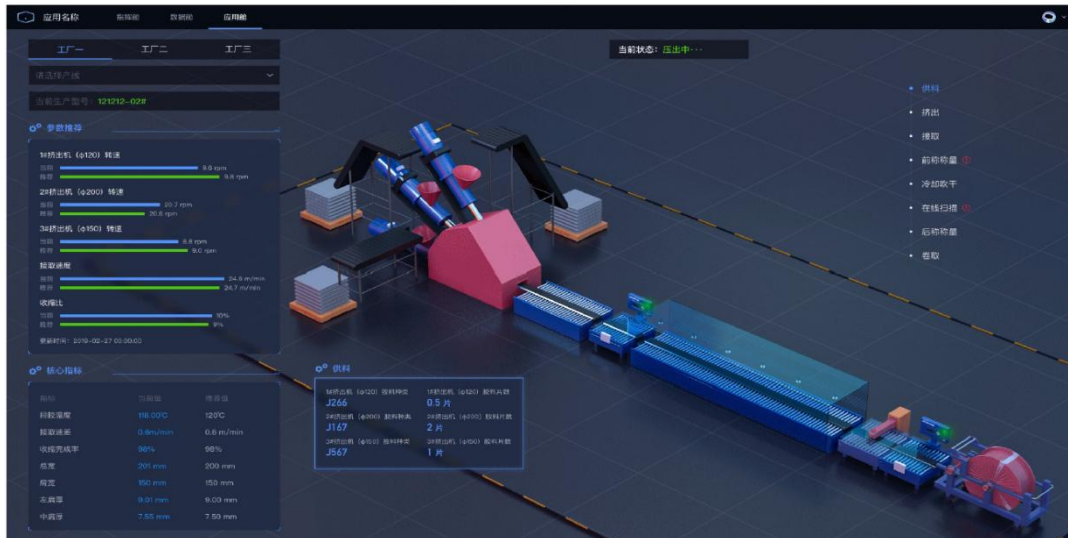


Figure 3: Intelligent Digital Extrusion Line Twin

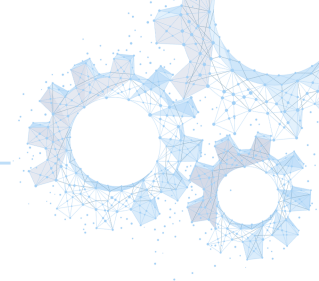
### 3. Operations Management: Digital Operations for Efficiency, Integrated Support for Warehousing, Energy, and Carbon Decision-Making

With the ERP system as the core, the factory has established an end-to-end process chain from customer orders to finished product delivery, ensuring efficient and smooth cross-border operations. A multi-tier early warning mechanism for the global supply chain has been built, along with a management system covering risk identification, real-time monitoring, tiered response, and closed-loop resolution, enhancing supply chain support and adaptability. In terms of logistics and warehousing, an intelligent automated warehouse plus an EMS unmanned transport model has been adopted, increasing

warehouse space utilization by 200% and reducing annual warehousing operating costs by over 40 million RMB. In terms of energy management, a smart energy-carbon dual-control management platform has been established, covering multiple energy media such as water, electricity, steam, compressed air, and nitrogen, with a total of 1,322 collection points, enabling real-time energy consumption monitoring, structural analysis, and intelligent optimization of energy-saving strategies. In terms of intelligent decision-making, a full-value-chain operations visualization cockpit has been created, aggregating multi-dimensional data on production, quality, energy consumption, and business operations to achieve dynamic monitoring and intelligent analysis of enterprise-level key KPIs, while also supporting routine data analysis across departments and within individual departments to assist business decision-making.



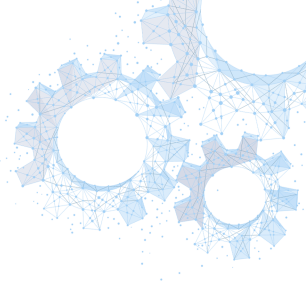
Figure 4: Smart Energy and Carbon Management Platform



### III. Implementation Effectiveness of the Overseas Factory

Through digital, intelligent, and green upgrading and construction, the factory has achieved significant results in operational efficiency, production costs, quality management, supply chain reliability, and green and low-carbon performance. First, multi-dimensional improvements in quality and efficiency have been realized: overall production efficiency increased by 42%, per capita output doubled, product defect rate decreased from 1.2% to 0.5%, first-pass yield for tire building reached 99.2%, comprehensive manufacturing cost per tire decreased by 18%, annual comprehensive cost reduction exceeded 120 million Thai baht, spare parts procurement cycle shortened by 55%, local sourcing rate in Thailand reached 75%, comprehensive energy consumption per unit of output value decreased by 18%, annual electricity savings reached 28 million kWh, and annual carbon reduction reached 28,000 tons. Second, a digital benchmark paradigm for the full value chain of the tire industry overseas has been established. the factory has successfully adapted the group's mature management experience to local Thai conditions, integrated digital links across all business domains including R&D, production, supply and sales, and service, achieved mixed-line production of 12

categories of radial tires, and adapted to the global market's demand for multi-category, small-batch, and short-delivery-cycle orders. Third, a demonstration base integrating intelligent manufacturing and green and low-carbon development has been created. By deeply integrating intelligent control with energy saving and carbon reduction, and leveraging measures such as energy-carbon dual control, distributed photovoltaics, and wastewater recycling, a low-carbon circular production model has been established, making the factory a landmark project for China-Thailand production capacity cooperation and high-quality Belt and Road Initiative development.



## 越南——海信电视机智能工厂

### 一、海外工厂整体情况

工厂坐落于越南同奈市隆城县，是海信集团为承接东南亚制造布局战略而成立的 TV 生产基地之一，主要生产 Hisense、Toshiba 品牌电视，覆盖东南亚、欧洲和美洲市场。工厂年产能 450 万台，构建了覆盖 32 吋至 116 吋全尺寸段的多元化产品矩阵，精准满足不同消费层级需求。从入门级 2K 电视到旗舰级 8K 超高清显示，产品线横跨高中低端市场，依托多品牌战略与阶梯式技术布局，持续引领显示技术革新。通过 AI 智能体、大数据、VR、仿真等技术，实现客户需求的精准研发、产品功能的快速迭代、供应链的敏捷响应以及全员赋能的极致品控。工厂是海信视像将全球顶尖智能制造能力与深度聚焦出海战略相结合的产物，既是“技术领先+绿色共生”的中国样本，也是“一带一路”沿线的智能制造示范工厂。

### 二、重点环节智能化建设情况

工厂将“以智能化为核心”的先进制造模式提升至战略高度，将三维仿真、人工智能、云计算、5G 网络等信息技术与 IT 系统结合，构建“一中心三平台”——矩阵式柔性制造中心、研发工艺一体化平台、供应链全生命周期管理平台、数智精益管理平台，打通从用户需求管理到产品定义、设计、开发、工艺、计划、采购、生产、销售及设备端的全链条数据流，进而优化资源配置效

率，快速响应订单变化，全面提升工厂的数字化水平与服务能力，形成高适配、高协同的海外智能工厂运营创新模式。

## 1. 智能工厂总体架构

工厂构建“云-边-端”协同的数字化架构，横向打通研发、工艺、生产、仓储、供应链及运营全价值链，纵向贯通设备层、控制层与运营层，深度集成 WMS、SCP、SRM、QMS、IoT 及 AI 中台等系统，并融合 Hi 智屏、BOP、HIWAY 等平台，形成“研产供销服”一体化协同体系，支撑一键换产、AI 质检、预测性维护及智能排产等核心应用，构建起高柔性、高协同、可复制的海外电视智能制造标杆架构。

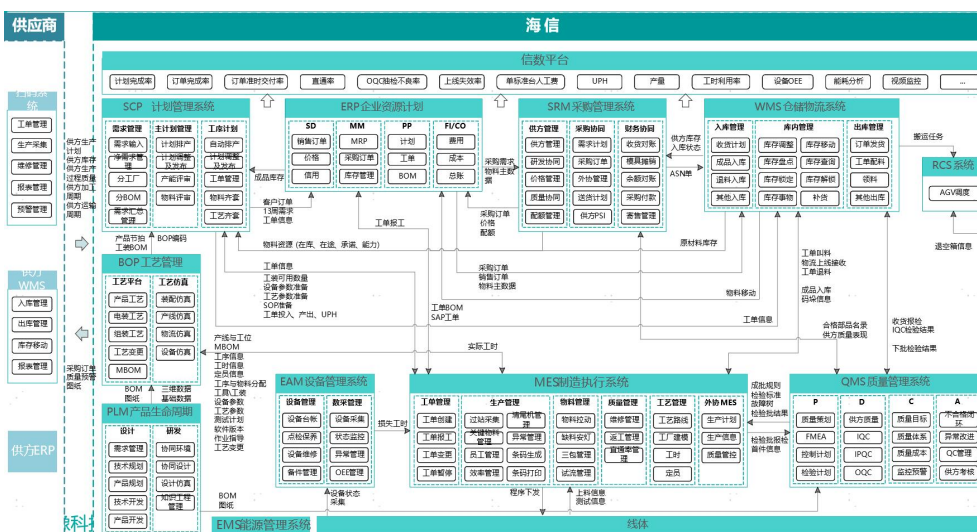


图 1 智能工厂总体架构

## 2. 研发设计：基于 MBD 的端到端一体化研发

工厂围绕先进制造，依托研发设计工艺一体化平台，打造需求、设计、工艺、制造一体化的研发体系，提升端到端交付能力；以 MBD（基于模型的定义）技术为核心，通过仿真技术提前进行虚拟验证，打造数字孪生场景，实现虚实结合的开发模式。拉

通研发、工艺、制造端到端的数据，形成数据同源、需求可追溯、跨领域、跨专业的业务协同，推动研发设计工艺平台持续数字化变革。

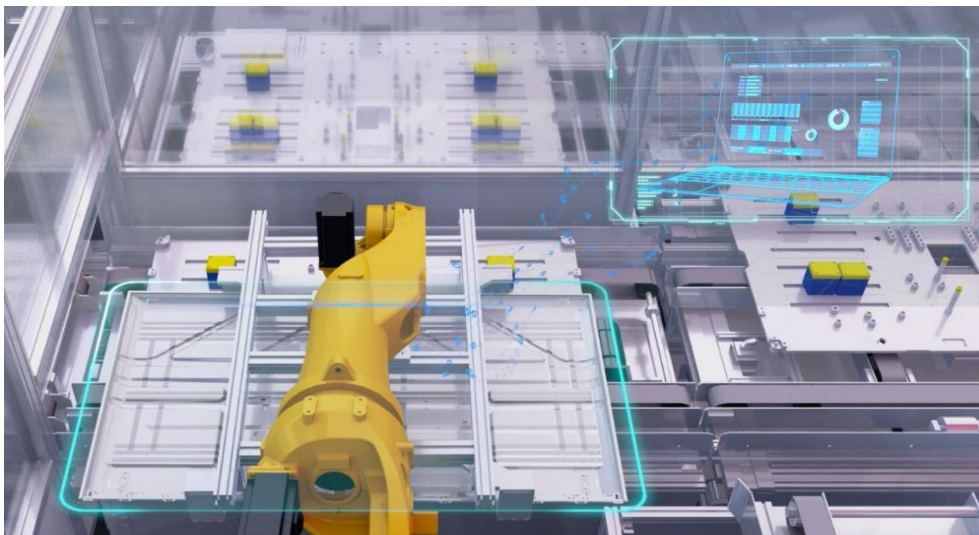


图 2： 三维仿真

### 3. 生产制造： AI 赋能柔性制造与绿色安全

生产制造环节搭建矩阵式柔性制造中心，引入自动螺钉锁固协作式机器人、CCD 工业相机 AOI+AI 画面检测、智能物流机器人、5G+AR/MR 终端及控制系统等，适配多品类、多型号产品的柔性生产，实现电视产品协同设计、柔性化生产检测、设备预测维护、智能仓储物流、能源高效集控及安全能源一体化管控等应用示范。

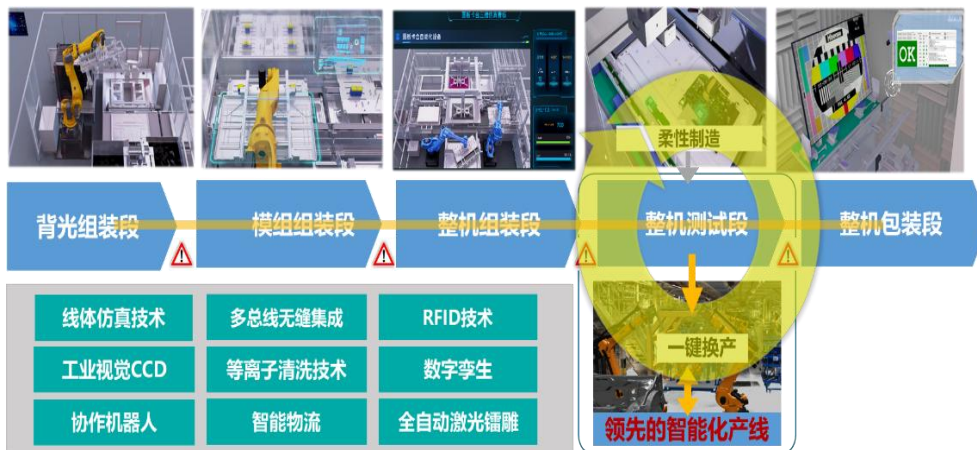


图 3 矩阵式柔性制造中心

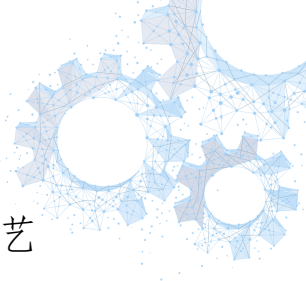
#### 4. 运营管理：数据驱动全流程精益管控

构建供应链全生命周期管理平台与数智精益管理平台，集成各类业务系统，实现订单到交付的全流程贯通；打通 SRM、MES、WMS 等系统数据，通过精益方法对生产现场、管理流程等进行科学优化及固化，打通企业间的数据流与业务流；以系统工程思想为指导，以项目管理为主线，建立工厂、车间、产线多级管控。同时，运用大数据自动完成供应商评级考评、风险预判及配送协同调度，实现全流程线上闭环管控与数据驱动的精细化运营管理。



图 4 供应商绩效评价

### 三、工厂实施成效



一是研发周期大幅缩短，依托大数据与三维仿真构建工艺知识库，使工艺设计周期缩短 15%、样品加工周期缩短 32%。二是生产效率和产品良率显著提升，生产效率提升 35%、装配不良率下降 67%、产品一次性合格率达 99.92%、设备综合效率（OEE）提升 15%、物料周转率提升 25%。三是运营成本有效降低，实现供应链风险智能预警与精益改善闭环，运营成本下降 46%。四是涌现多项行业首创技术，首创自适应“点胶+喷胶”矩阵式智能单元，实现胶水利用率行业第一；首创数字化生产单元智能中控神经网络终端，有效填补了东南亚电视行业产线智能集控系统的空白。



图 5 AI 加持的设备首台套

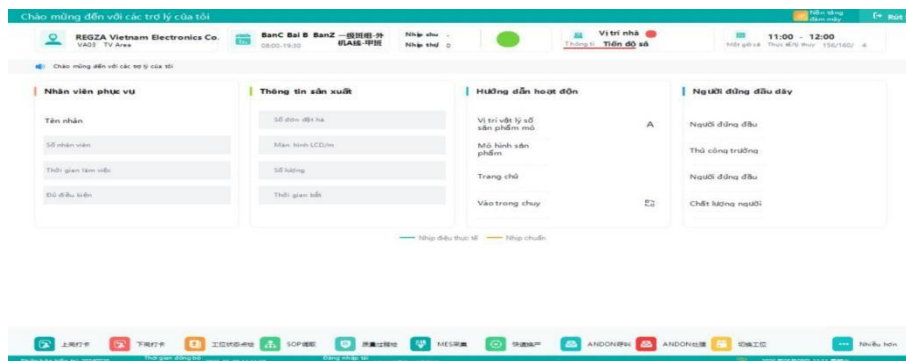


图 6 智能中控神经网络终端系统截图

## **Vietnam—Hisense TV Smart Factory**

### **I. Overview of the Overseas Factory**

Located in Long Thanh District, Dong Nai City, Vietnam, the factory is one of the TV production bases established by Hisense Group to execute its Southeast Asia manufacturing layout strategy. It primarily produces Hisense and Toshiba brand televisions, covering markets in Southeast Asia, Europe, and the Americas. With an annual production capacity of 4.5 million units, the factory has built a diversified product matrix covering the full size range from 32 inches to 116 inches, precisely meeting the needs of different consumer segments. From entry-level 2K TVs to flagship 8K ultra-high-definition displays, the product line spans the high, mid, and low-end markets. Leveraging a multi-brand strategy and a tiered technology roadmap, the factory continues to lead innovation in display technology. By utilizing technologies such as AI agents, big data, VR, and simulation, the factory achieves precise R&D targeting customer needs, rapid iteration of product functions, agile supply chain response, and employee-driven quality control that pursues excellence. the factory represents the integration of Hisense Visual Technology's world-class intelligent manufacturing capabilities with a deep focus on its global expansion strategy. It serves as both a "technology-leading + green

sympiosis" model from China and a demonstration smart factory along the Belt and Road Initiative.

## **II. Status of Intelligent Construction in Key Areas**

the factory has elevated the advanced manufacturing model centered on "intelligence as the core" to a strategic level. By integrating information technologies such as 3D simulation, artificial intelligence, cloud computing, and 5G networks with IT systems, the factory has built a "One Center, Three Platforms" architecture — namely, a matrix-based flexible manufacturing center, an integrated R&D and process platform, a full-lifecycle supply chain management platform, and a digital-intelligent lean management platform. This architecture connects the end-to-end data flow from user demand management to product definition, design, development, process engineering, planning, procurement, production, sales, and equipment. As a result, resource allocation efficiency is optimized, order changes are responded to rapidly, and the factory's digital capabilities and service levels are comprehensively enhanced, forming an innovative operation model for overseas smart factories that is highly adaptable and collaborative.

### **1. Overall Factory Architecture**

the factory has established a "cloud-edge-device" collaborative digital architecture. Horizontally, it integrates the entire value chain of R&D, process engineering, production, warehousing, supply chain, and operations. Vertically, it connects the equipment layer, control layer, and operations layer. Systems such as WMS, SCP, SRM, QMS, IoT, and an AI middleware platform are deeply integrated, along with platforms like Hi Smart Screen, BOP, and HIWAY, forming a collaborative system that unites "R&D, production, supply, sales, and service." This architecture supports core applications such as one-click model changeover, AI quality inspection, predictive maintenance, and intelligent production scheduling, establishing a highly flexible, highly collaborative, and replicable benchmark architecture for overseas TV intelligent manufacturing.

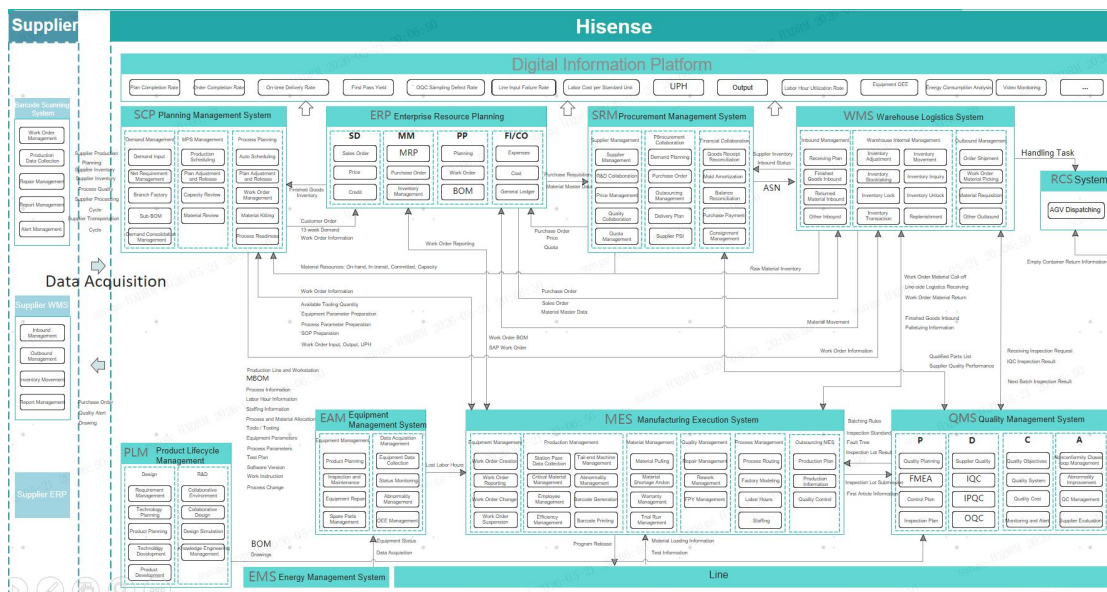
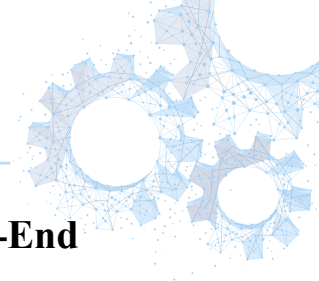


Figure 1: Overall Architecture of the Smart Factory



## **2. Research & Development and Design: MBD-Based End-to-End Integrated Research & Development**

Focusing on advanced manufacturing, the factory has established an integrated Research & Development system encompassing requirements, design, process engineering, and manufacturing, leveraging an Research & Development and process integration platform to enhance end-to-end delivery capabilities. With MBD (Model-Based Definition) technology as the core, virtual verification is conducted in advance through simulation technologies to create digital twin scenarios, enabling a development model that combines virtual and physical approaches. By connecting end-to-end data across R&D, process engineering, and manufacturing, the factory achieves data consistency, traceable requirements, and cross-domain, cross-discipline business collaboration, driving continuous digital transformation of the Research & Development and design process platform.: MBD-Based End-to-End Integrated Research & Development.

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platform to enhance end-to-end delivery capabilities. With MBD (Model-Based Definition) technology as the core, virtual verification is conducted in advance through simulation technologies to create digital twin scenarios, enabling a development model that combines virtual and physical approaches. By connecting end-to-end data across Research & Development, process engineering, and manufacturing, the factory achieves data consistency, traceable requirements, and cross-domain, cross-discipline business collaboration, driving continuous digital transformation of the Research & Development and design process platform.

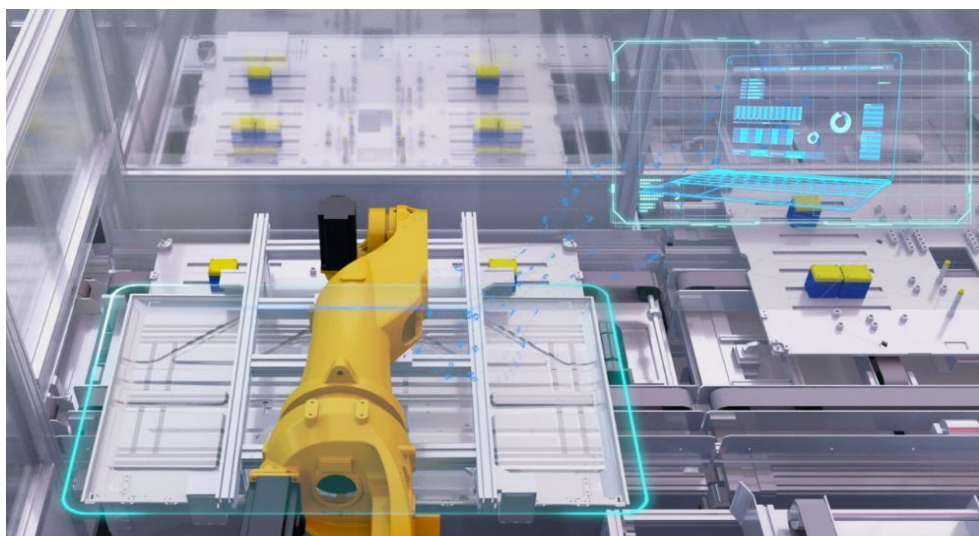
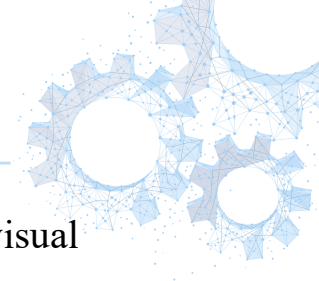


Figure 2: 3D Simulation

### **3. Production and Manufacturing: AI-Empowered Flexible Manufacturing, Green and Safe Operations**

In the production and manufacturing process, a matrix-based flexible manufacturing center has been established. Collaborative robots for



automatic screw locking, CCD industrial cameras with AOI+AI visual inspection, intelligent logistics robots, 5G+AR/MR terminals and control systems, among other technologies, have been introduced to support flexible production of multiple product categories and models. Demonstration applications have been realized, including collaborative design of TV products, flexible production and inspection, predictive equipment maintenance, intelligent warehousing and logistics, centralized and efficient energy control, as well as integrated safety and energy management.

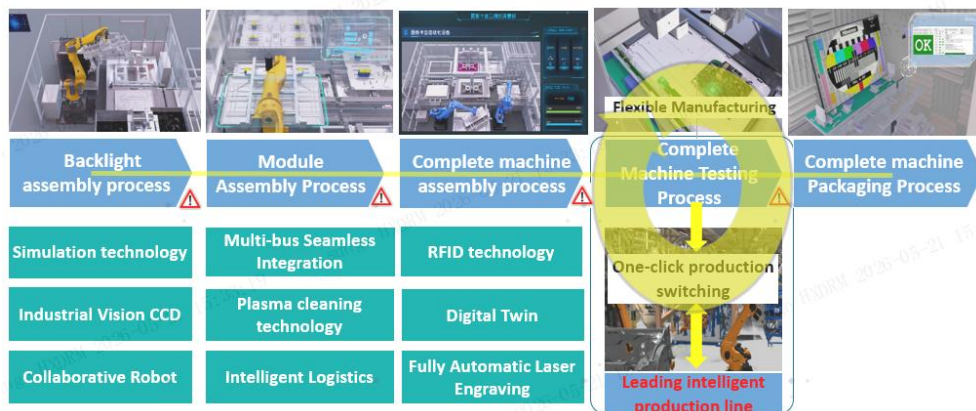


Figure 3: Matrix Flexible Manufacturing Center

#### 4. Operations Management: Data-Driven Lean Control Across the Entire Process

A full-lifecycle supply chain management platform and a digital-intelligent lean management platform have been established, integrating various business systems to achieve end-to-end process integration from order to delivery. Data from systems such as SRM,

MES, and WMS are connected, and lean methodologies are applied to scientifically optimize and standardize production sites and management processes, enabling seamless data and business flows across enterprises. Guided by systems engineering principles and with project management as the main thread, multi-level management and control are implemented at the factory, workshop, and production line levels. Additionally, big data is utilized to automatically conduct supplier rating assessments, risk prediction, and distribution coordination, achieving closed-loop online management and control across the entire process as well as data-driven refined operations management.

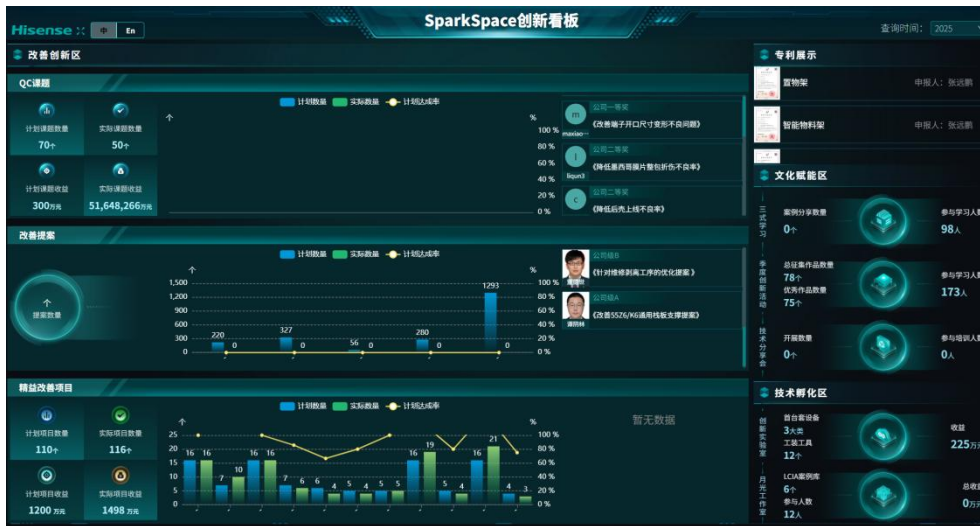
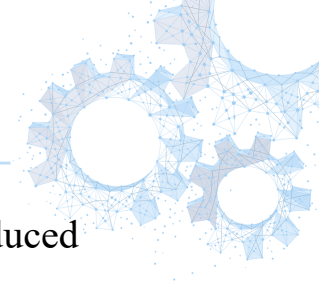


Figure 4: Supplier Performance Evaluation

### III. Implementation Effectiveness of the Overseas Factory

First, the Research & Development cycle has been significantly shortened. By leveraging big data and 3D simulation to build a



process knowledge base, the process design cycle has been reduced by 15%, and the sample processing cycle has been shortened by 32%. Second, production efficiency and product yield have been significantly improved. Production efficiency has increased by 35%, the assembly defect rate has decreased by 67%, the first-pass yield has reached 99.92%, overall equipment effectiveness (OEE) has improved by 15%, and material turnover rate has increased by 25%. Third, operating costs have been effectively reduced. Intelligent early warning for supply chain risks and a closed-loop lean improvement system have been realized, reducing operating costs by 46%. Fourth, a number of industry-first technologies have been developed. The industry-first adaptive "dispensing + spraying" matrix-based intelligent unit has achieved the highest adhesive utilization rate in the industry. The industry-first digital production unit intelligent central control neural network terminal has effectively filled the gap in intelligent centralized control systems for production lines in the Southeast Asian TV industry.

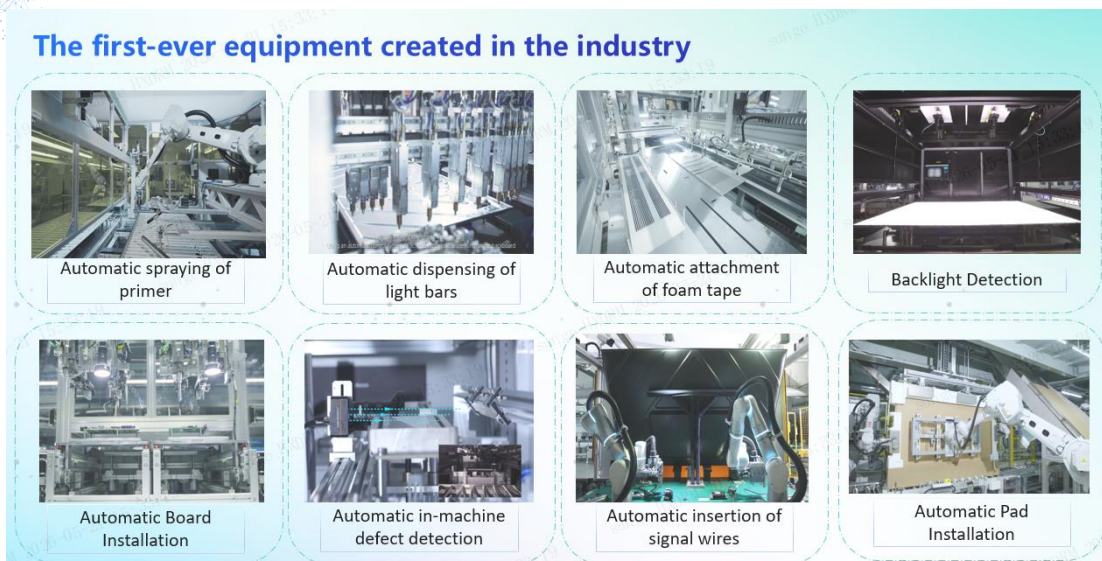


Figure 5: First Set of AI-Enhanced Equipment

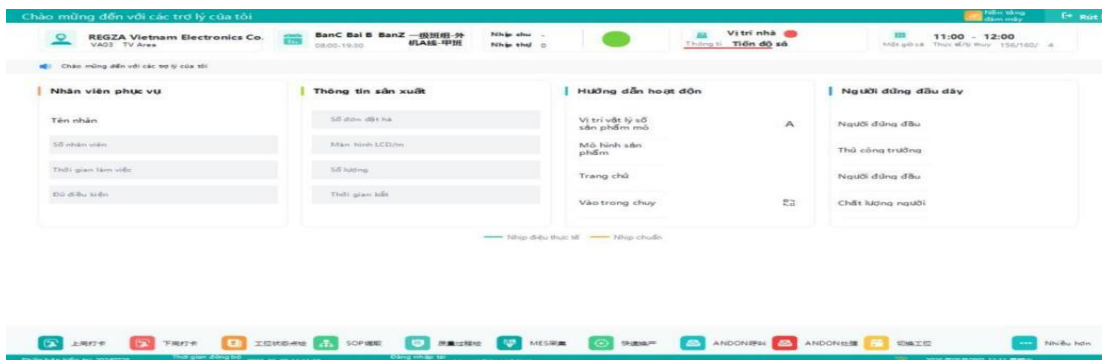


Figure 6: Screenshot of the Intelligent Central Control Neural Network Terminal System