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Flexible manufacturing systems and their role in human resource sustainability:  
Analytical study

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ABSTRACT

**BACKGROUND AND OBJECTIVES:** This study investigated how Flexible Manufacturing Systems—including workstations, automated handling/storage, inspection equipment, ancillary components, and computer control—were related to Human Resource sustainability (justice, job well-being, and employee development) at the Samarra Pharmaceutical Factory. The objective was to identify which FMS dimensions most strongly supported sustainable HR outcomes.

**METHODS:** A descriptive–analytical design was used. A structured questionnaire was administered to 230 employees; 207 valid responses were obtained (response rate = 90%). The measurement model and hypotheses were tested in AMOS v26 using standard validation criteria and structural equation modeling.

**RESULTS:** Overall FMS capability was positively associated with HR sustainability (standardized regression weight = 0.932; unstandardized estimate = 2.079; 95% CI = 0.896–0.971;  $p = 0.02$ ). Bivariate correlations between individual FMS components and HR sustainability were significant: workstations  $r = 0.841$  ( $\alpha = 0.05$ ), handling & storage  $r = 0.833$  ( $\alpha = 0.05$ ), inspection equipment  $r = 0.644$  ( $\alpha = 0.05$ ), computer control systems  $r = 0.902$  ( $\alpha = 0.05$ ), and other components  $r = 0.928$  ( $\alpha = 0.05$ ). Model fit indices met accepted thresholds (e.g., GFI = 0.927, AGFI = 0.916, RMR = 0.068, NFI = 0.913, RFI = 0.905).

**CONCLUSION:** Strengthening Flexible Manufacturing Systems—particularly computer control systems—was associated with higher HR sustainability by improving safety, reducing physical/psychological strain, and expanding development opportunities. Managers seeking technology investments that advance operational efficiency and workforce well-being could prioritize FMS upgrades aligned with these results.

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## INTRODUCTION

The modern business landscape is evolving rapidly under the pressures of technological advancement, globalization, intensifying competition, and the growing salience of sustainability. These forces pose a central challenge for organizational leaders: reconciling short-term profitability with the development of long-term capabilities that secure survival and growth. In this milieu, sustainability has broadened beyond its environmental origins of the 1970s to encompass an integrated perspective that includes economic and social dimensions. Organizations pursue sustainability because strategically valuable, scarce, and hard-to-imitate resources are foundational to lasting competitive advantage. Chief among these is human capital—a distinctive strategic asset that creates value through interactions at the individual, organizational, and societal levels. Advancing sustainability, therefore, cannot occur in isolation at any single level; rather, it requires balancing the needs and aspirations of stakeholders across all three levels simultaneously within the organization (Ehnert, 2006). Insufficient attention to sustainability in the business sector has contributed to economic slowdowns, prompting firms to adopt innovative responses. Flexible Manufacturing Systems (FMS) represent one such strategic response, enabling the creation of a culture that aligns day-to-day operations with long-term strategic objectives. This study focuses on how FMS can strengthen human resource sustainability by improving employee well-being and building workforce capabilities. Accordingly, the work is organized into four sections. The first outlines the research methodology. The second develops the theoretical foundations and clarifies the variables and dimensions under study. The third presents the empirical component. The fourth offers the principal conclusions and actionable recommendations derived from the analysis. Together, these sections explain the pathways through which FMS can enhance human resource sustainability while reinforcing organizational resilience and performance. To achieve the paper's objectives, the research survey was conducted at Samarra Pharmaceutical Factory in Iraq in 2025. In practice, many organizations adopt flexible manufacturing systems to improve efficiency, yet the implications of these systems for the long-term sustainability of their human resources remain unclear. In particular, there is limited empirical evidence on whether the main components of FMS—workstations, automated han-

dling and storage, inspection equipment, computer control systems, and other supporting elements—actually contribute to justice, job well-being, and employee development within industrial settings such as the Samarra Pharmaceutical Factory. In response to this gap, the present study pursues three main targets: (1) to assess employees' perceptions of the presence and maturity of FMS components in the factory; (2) to estimate the influence of overall FMS capability and each of its components on human resource sustainability; and (3) to identify which FMS components most strongly support sustainable human resource outcomes, thereby providing practical priorities for managers in pharmaceutical manufacturing.

### Research problem

Modern organizations increasingly recognize that achieving their objectives requires adopting sustainability across their environmental, social, and economic dimensions. Sustainability today goes beyond improving corporate image or gaining a competitive edge; it also exerts a direct and positive influence on employees. Despite this recognition, many organizations continue to confine sustainability to corporate social responsibility activities, failing to integrate it into the core of their operations—an oversight that can have serious long-term consequences. Since human resources constitute the intellect and driving force of any organization, sustainability must begin with individuals and be reflected in HR policies. This is particularly critical in modern workplaces that depend on FMS, which demand renewable skills and high adaptability (Cherian & Farouk, 2017). Neglecting to embed sustainability principles within such environments can weaken an organization's ability to retain and develop skilled personnel, ultimately undermining overall performance. Accordingly, the central research problem is framed in the following question:

How can organizations that adopt flexible manufacturing systems integrate sustainability principles into their human resource management practices? This overarching question leads to three sub-questions:

- A. Are the research variables and dimensions present in the studied field?
- B. *In what ways do FMSs contribute to Human Resource Sustainability (HRS)?*
- C. Is there a significant relationship between flexible manufacturing systems and HRS within the company?

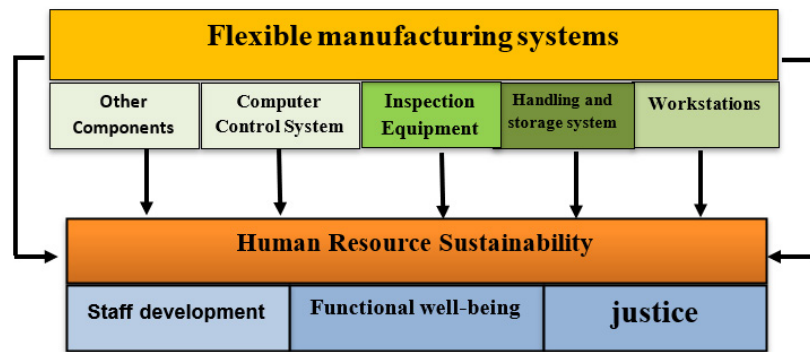


Fig. 1: The relationships serve as the basis for empirical testing

### Research objective

The main objective of this study is to highlight the role of FMSs in achieving HRS, thereby enabling adopting organizations to strengthen their market position and achieve distinctiveness over competitors. To meet this aim, the study pursues three sub-objectives:

- A. Assessing the extent to which employees recognize the importance of adopting flexible manufacturing systems.
- B. Analyzing the contribution of flexible manufacturing systems to achieving human resource sustainability.
- C. Measuring and evaluating the relationship between flexible manufacturing systems and human resource sustainability.

### Research importance

This research carries significant methodological and practical value, especially in the Iraqi industrial context:

- A. *Bridging a research gap*: While existing studies on flexible manufacturing systems primarily emphasize technological and production aspects, they often overlook implications for the human element. This study addresses that gap by examining how FMS affects human resource sustainability.
- B. *Addressing industry challenges*: Modern industries—particularly pharmaceuticals and medical supplies—face challenges linked to adapting to rapid market fluctuations and evolving customer needs. FMS provides a strategic response to these challenges, but its success depends on the adaptability and continuous learning of human resources. Thus, this study underscores how FMS can support rather than replace workers.
- C. *Advancing sustainable development*: Sustaining hu-

man resources is a cornerstone of organizational sustainable development. By maintaining and developing employee competencies, organizations can ensure ongoing productivity and innovation. This research demonstrates the role of FMS in this regard.

D. *Providing actionable recommendations*: The study seeks to deliver practical and applicable recommendations suited to the capacities of industrial organizations, particularly in the pharmaceutical and medical supply sectors.

### Hypothetical research plan

Addressing the research problem requires a structured framework that clarifies the relationships between the study's variables and their dimensions. The proposed research model, illustrated in Fig. 1, depicts these relationships and serves as the basis for empirical testing.

### Research hypotheses

To guide empirical testing, the study proposes the following hypotheses:

- Hypothesis 1 (H1)*. The collective components of flexible manufacturing systems exert a significant statistical effect on human resource sustainability, considered as a composite construct within the focal organization.
- Hypothesis 2 (H2)*. Each component of flexible manufacturing systems has a significant statistical effect on human resource sustainability, considered as a composite construct within the focal organization.

## MATERIALS AND METHODS

The study employs a descriptive–analytical approach. A desk- and web-based literature review was conducted to develop the theoretical framework. Pri-

mary data were gathered through a structured questionnaire administered in the field, and subsequently analyzed with appropriate statistical techniques to test the proposed hypotheses. The theoretical framework presented in the previous section conceptualizes flexible manufacturing systems as a multidimensional construct comprising workstations, handling and storage systems, inspection equipment, computer control systems, and other supporting components, while human resource sustainability is defined through justice, job well-being, and employee development. These conceptual dimensions directly informed the design of the questionnaire: items were grouped according to the corresponding FMS and HRS dimensions and adapted from established studies in manufacturing flexibility and sustainable HRM. On this basis, structural equation modeling was selected as the main analytical technique because it allows simultaneous estimation of measurement models (via confirmatory factor analysis) and structural paths between latent variables. Thus, the empirical strategy is explicitly derived from the theoretical model illustrated in Fig. 1 and from the hypotheses formulated for H1 and H2.

#### *Research boundaries*

Clear boundaries were established to define the scope of the inquiry:

*Temporal Scope:* The research (theoretical and field-work) was conducted between June 25, 2025, and September 2, 2025.

*Spatial scope:* The empirical setting is the General Company for the Manufacture of Medical Equipment and Supplies / Samarra Pharmaceutical Factory, selected as a mature organization that has operated under diverse leadership styles.

*Human scope:* The sample comprises employees working at the above organization.

#### *Data collection*

Data were collected using a questionnaire and interviews administered to a randomly selected group of employees. A total of 230 questionnaires were distributed; 207 were returned, yielding a 90% response rate. The instrument comprised two main sections: Items measuring flexible manufacturing systems and items measuring human resource sustainability. All variables and dimensions were assessed using a five-point Likert scale.

#### *Sampling adequacy tests*

Before conducting factor analysis, the suitability of the data for multivariate analysis was examined using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett’s test of sphericity. The overall KMO statistic was 0.79, which exceeds the commonly recommended threshold of 0.60 and indicates that the items share a sufficient level of common variance. Bartlett’s test of sphericity was also highly significant ( $\chi^2 = 1120.3$ ,  $df = 276$ ,  $p < 0.001$ ), confirming that the correlation matrix is not an identity matrix and that the data are appropriate for factor-analytic procedures.

#### *Theoretical framework*

##### *FMS*

##### *Concept of FMS*

The notion of FMS emerged in the 1960s with the integration of robots, programmable controllers, and digital control into computer-operated machinery. FMS can be described as an interconnected set of digitally controlled tools and machines managed by a central computer system. Work cells are linked through automated loading/unloading units and conveying systems, allowing efficient coordination across operations. Such systems enhance operational adaptability by executing manufacturing tasks for multiple product designs in small batches with shorter delivery times. In this way, FMS functions as an automated production model capable of producing one or more sets of parts with flexibility to sustain competitiveness (Kostal & Velisek, 2011). Contemporary manufacturing environments face new challenges—marked by complexity, product variety, and a demand for higher customization. This has increased reliance on FMS, which are particularly suited to accommodate product diversity (Lafou et al., 2016). Kaushal et al., (2016) define FMS as a highly automated cell of machines connected by automated material handling and storage, overseen by a distributed computer system. Similarly, Shukla and Gangwar (2021, p. 641) describe it as the speed and efficiency with which a production line can shift from existing to new products. Groover (2008) and Kavaliauskiene et al., (2022) emphasize the integration of multiple processing stations and computer-based control, while Hamidi (2018) highlights machine groups supported by electronic handling and storage. More recently, Al-Ghanam (2022) views FMS as a set of tools designed to reduce non-value-adding activities, eliminate waste, and support continuous production improvement.

### Advantages of FSM

Flexible manufacturing systems help organizations meet specialized production needs while responding swiftly to changing market demands. By lowering inventory levels, reducing lead times, and producing high-quality goods at competitive costs, FMS provides organizations with an effective mechanism to expand market share (Groover, 2008). Some of the primary advantages include:

- Workstation control via computerized systems.
- Centralized control instructions coordinating multiple stations.
- Production control for product mix, scheduling, and planning.
- Traffic control to regulate the flow of parts between stations.
- Shuttle control to align primary and secondary handling systems.
- Workpiece monitoring to track the status of parts throughout production.
- According to Al-Ghannam (2022), additional benefits include first-time quality through early problem detection, waste reduction, continuous improvement, cost efficiency, productivity gains, adoption of pull systems, and rapid adaptability to varying product specifications.

### Types of flexibility in FMS

Flexibility is the distinguishing attribute of FMS, enabling uninterrupted production despite shifts in product design or demand. A system that can simultaneously process multiple product models and adjust output volumes accordingly is considered flexible (Kaushal et al., 2016; Kumar et al., 2017). The main types include:

*Machine flexibility* – the ability of machines to perform diverse operations, influenced by setup time, tool storage, programming ease, and operator skills.

*Production flexibility* – the scope of part designs producible within acceptable cost and time, determined by the range of processes supported across stations.

*Mix flexibility* – the ability to vary product proportions while maintaining constant overall output, thus mitigating market volatility.

*Product flexibility* – the capacity to shift quickly and economically to new product lines, depending on design compatibility and machine adaptability.

*Volume flexibility* – the ability to adjust production volumes to meet demand fluctuations while retaining profitability.

Shukla Gangwar (2021) & Ewis et al., (2025) classify flexibility into machine flexibility, where specific machines produce varied products, and routing flexibility, where multiple machines can perform the same process.

### Key components of FMS

Globalization and shifting market dynamics have compelled industries to prioritize responsiveness, quality, and customer satisfaction over mere cost reduction. FMS integrates automation, robotics, and advanced planning tools (e.g., JIT, PPC, ERP) to meet these needs (Kaushal et al., 2016). According to Kostal and Velisek (2011), FMS rely on three primary subsystems—machine tools, material-handling systems, and computer control—coordinated to achieve end-to-end automation from design to storage. Once a part passes through technological processing, it undergoes inspection; approved items are stored automatically, while defective ones are routed to designated storage areas, all without human intervention. Kaushal et al., (2016) identify the following essential components: Workstations – CNC machine tools, machining centers, inspection and assembly units, presses, and forming stations.

*Automated Material Handling and Storage Systems (AMHS)* – systems enabling random transfer, temporary storage, and seamless integration with computer controls.

Inspection equipment – such as coordinate measuring machines programmed for dimensional and surface accuracy.

*Computer Control System (CCS)* – managing workstation activities, material flow, production scheduling, system monitoring, and reporting.

*Other supporting components* – sensors, inspection tools, temporary storage, and skilled human resources- all contribute to system efficiency, adaptability, and organizational success.

### HRS

*Concept:* During the final decades of the twentieth century, the strategic approach to Human Resource Management (HRM) emphasized compliance with legal requirements, reducing litigation, and supporting organizational economic goals. In the twenty-first century, however, the discourse has shifted toward sustainability. A sustainable society cannot be achieved without organizations safeguarding the sustainability of their human resources. In this context, HRS refers

to practices that simultaneously enhance economic, social, and environmental performance while promoting long-term employee well-being, satisfaction, and commitment. Its essence lies in creating workplace conditions that balance organizational objectives with the quality of employees' professional lives (Genari, 2022). Sustainability encompasses two complementary aspects: the sustainability of human resources, which involves meeting evolving human needs, and environmental sustainability, which relates to protecting ecosystems while recognizing the interdependence of people and nature (Spooner & Kaine, 2010). An HRS framework typically includes transparent procedures for recruitment, retention, training, performance management, and motivation. Its long-term orientation emphasizes socially responsible policies that enhance engagement and reduce turnover. Success is thus measured not only financially but also by social and environmental contributions (Cherian & Farouk, 2017; Vanka et al., 2020). In practice, HRS means planning, attracting, and supporting employees in ways that allow them to achieve the organization's economic, social, and environmental goals, while ensuring intergenerational equity (Sas, 2022). As Lu et al., (2023) observe, HRS emerges when HRM adopts policies and strategies enabling employees to actively pursue organizations' long-term triple-bottom-line objectives.

#### *Importance of HRS*

Organizations that embrace sustainability can reduce costs and expand revenues through improved efficiency, innovation, and growth. However, many change initiatives fail due to neglect of the human dimension, where goals are set without adequate consideration of employee roles in achieving them (Spooner & Kaine, 2010; Schroeder, 2012). Implementing HRS policies fosters a productive, motivated workforce that contributes not only to financial success but also to social and environmental advancement. Employees in such organizations feel stronger connections to their employers, reinforcing loyalty and long-term commitment (Cherian & Farouk, 2017). The concept further guards against exploitation of human capital by preserving and enhancing knowledge, skills, and physical capacity. Motivated and engaged employees become catalysts for achieving sustainable development. According to Sas (2022) and Dumitran et al., (2009), the importance of HRS can be summarized as follows:

- Supporting the organization's sustainability strategy.
- Ensuring fairness and employee well-being.
- Developing skills and confidence that reinforce commitment to sustainability.
- Addressing both internal stakeholders (employees) and external ones (partners and communities).
- Promoting environmentally responsible practices.

Additionally, HRS strengthens competitiveness by attracting and retaining talent, promoting workplace justice, safeguarding occupational health and safety, and embedding social responsibility into corporate culture (Anlesinya & Pattanee, 2020).

#### *Requirements for HRS*

HR professionals are uniquely positioned to drive sustainability within organizations. Key requirements include (Schroeder, 2012):

- Awareness and Dialogue. Building employee awareness of sustainability through training, workshops, newsletters, and digital resources to encourage participation and commitment.
- Technical and Scientific Competence. Ensuring adequate skills for sustainability implementation through training or targeted recruitment, along with systematic skills audits.
- HR Policies and Processes. Revising performance management, recruitment, and reward systems to integrate sustainability factors into competencies and job descriptions.
- Socially Responsible Recruitment. Aligning hiring practices with corporate social responsibility by attracting employees who value sustainability, ensuring fair employment terms, and training suppliers as well as internal staff.

Expanding on this, Anlesinya and Pattanee (2020) and Liu (2024) highlight additional requirements, including long-term workforce planning, employee well-being, environmentally friendly behaviors, profitability and engagement programs, active participation and social dialogue, job rotation and training, stakeholder partnerships, flexible work arrangements, compliance beyond statutory minimums, teamwork and cooperation, and promotion of fairness and equality in wages and opportunities.

### *Dimensions of HRS*

Sustainability concerns have increasingly drawn academic attention to HR, labor relations, and the role of organizations in advancing sustainable development. HRS is frequently associated with employee engagement and emotional well-being, reinforcing the idea that employees are the foundation of organizational sustainability (Spoonner & Kaine, 2010). According to Stankeviciute and Savaneviciene (2018), HRS emphasizes employability, personal responsibility, and work–life balance, conceptualized through three key dimensions: justice, job well-being, and employee development. These align with the current study’s framework. Justice. Justice reflects fairness in treatment, whether understood as equality or as recognition of individual differences (Jones *et al.*, 2010). Research highlights its role in shaping trust, citizenship behaviors, and innovation, both within and between organizations (Yeoman & Santos, 2016). Balal (2025) stresses that justice directly influences performance by shaping how employees perceive organizational fairness through social, moral, and religious values. Well-being encompasses positive emotions, psychological stability, and workplace satisfaction. It includes life, workplace, and psychological dimensions (Al-Abadi, 2017). Practices supporting well-being range from health programs and stress-free environments to activities that enhance motivation and productivity (Al-Awimer & Al-Shabli, 2024). Employee Development. Training and development are essential for equipping employees with evolving skills. Training provides knowledge and technical expertise, while development prepares staff for higher responsibilities and long-term adaptability. Continuous investment in employee development ensures competitiveness in dynamic environments (Al-Khalayleh, 2019; Nashash, 2020; Stavros, 2022).

## **RESULTS AND FINDINGS**

### *Description of the research sample*

A purposive sample was selected, focusing on individuals who possess direct experience with—and awareness of—the laboratory’s operations and tasks. This approach was intended to ensure high-quality, actionable responses and to solicit ideas that could enrich the study’s contribution. In total, 230 questionnaires were distributed, and 207 usable responses were obtained for analysis, yielding a 90% response rate.

### *Sampling adequacy*

Preliminary diagnostics supported the factorability of the correlation matrix. The Kaiser–Meyer–Olkin measure of sampling adequacy reached 0.79, indicating acceptable shared variance among the observed variables. In addition, Bartlett’s test of sphericity was significant ( $\chi^2 = 1120.3$ ,  $df = 276$ ,  $p < 0.001$ ), demonstrating that the inter-item correlations are sufficiently large for factor analysis. These results justify the use of confirmatory factor analysis and structural equation modelling in testing the proposed relationships between flexible manufacturing systems and human resource sustainability.

### *Confirmatory Factor Analysis (CFA)*

CFA was employed to test the measurement model using standard goodness-of-fit criteria to judge acceptability and suitability for hypothesis testing. The analysis relied on the Scale-Free Least Squares (SLS) estimator, which typically presumes: (i) approximately normal data, (ii) absence of extreme outliers, and (iii) a sample size at least five to ten times the number of observed indicators. In the present dataset, these preconditions were not fully satisfied, as evidenced in Fig. 2 and Table 1, which document deviations from normality and sizing requirements.

From Table 1, the model’s fit indices are satisfactory and lie within accepted thresholds for measurement quality. Accordingly, the hypothesized model is retained without modification and deemed suitable for subsequent hypothesis testing.

### *Third hypothesis testing*

With the CFA confirming that the measurement model aligns with the field data and meets required fit standards, we proceed to test the study hypotheses as follows:

First Main Hypothesis Statement: There is a significant correlation between flexible manufacturing systems and human resource sustainability (overall). Result. As reported in Table 2, the correlation between flexible manufacturing systems and human resource sustainability (total) is positive and statistically significant, with . Therefore, the first main hypothesis is supported.

### *Sub-hypothesis (A) of the first main hypothesis*

There is a significant correlation between each component of flexible manufacturing systems and human resource sustainability. According to Table 3:

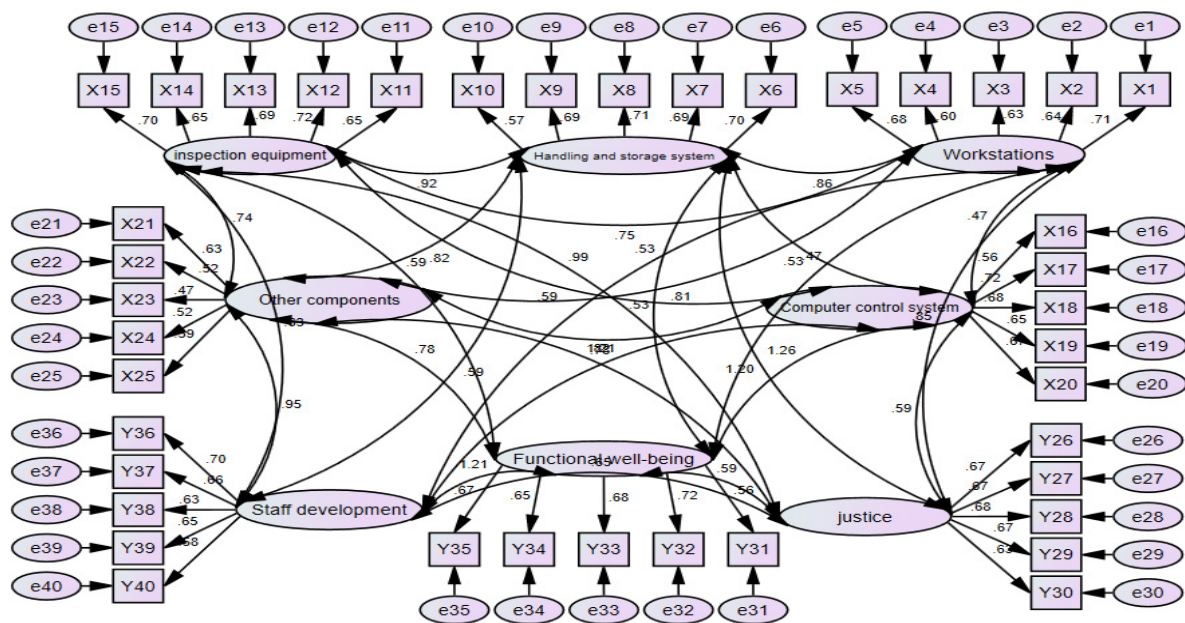


Fig. 2: The proposed prototype of the system

Table 1: Quality indicators of the initial research model

| Standard indicators | Acceptance limits                        | Model indicators | Matching result |
|---------------------|------------------------------------------|------------------|-----------------|
| GFI                 | 0.90 > GFI Model quality                 | 0.927            | Matching        |
| AGFI                | 0.90 > AGFI Best Match                   | 0.916            | Matching        |
| RMR                 | RMR value between 0.08 and zero          | 0.068            | Matching        |
| NFI                 | 0.90 > NFI Best Match                    | 0.913            | Matching        |
| RFI                 | 0.90 < (RFI) Data fit to model           | 0.905            | Matching        |
| PGFI                | The closer to (1), the better the match. | 0.805            | Matching        |
| PRATIO              | PRATIO > 0.90 Best Match                 | 0.913            | Matching        |

Table 2: The relationship between flexible manufacturing systems and human resource sustainability (combined)

| Dependent variable | independent variable          | Flexible Manufacturing Systems |
|--------------------|-------------------------------|--------------------------------|
|                    | Human Resource Sustainability | 0.932*                         |

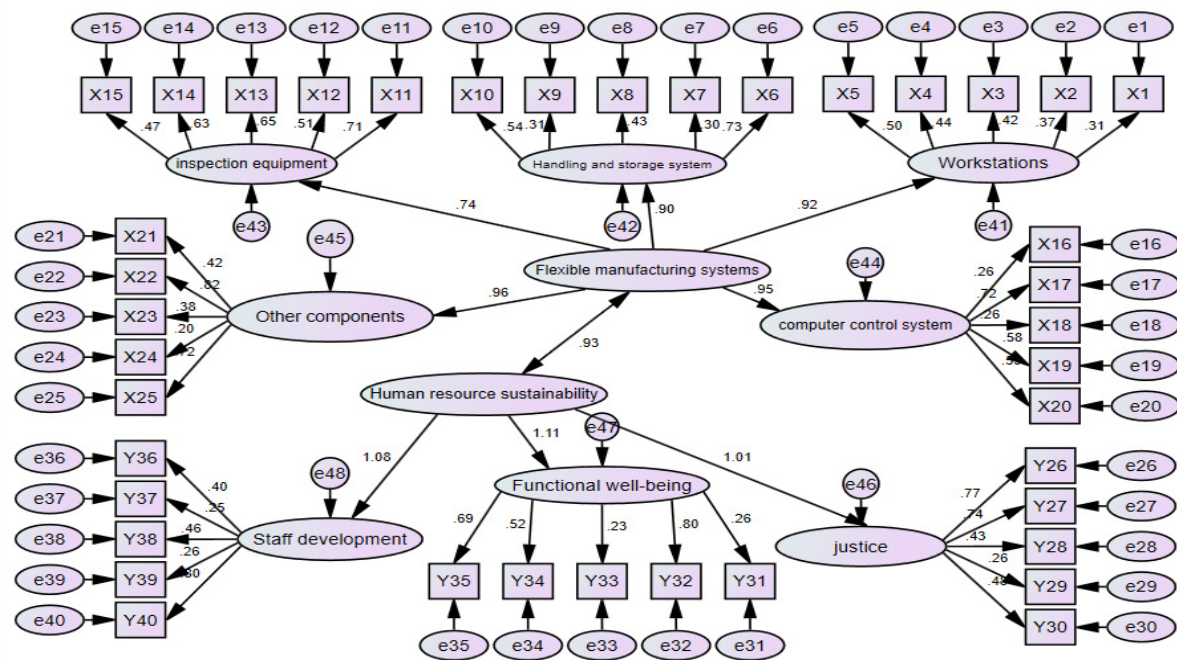


Fig. 3: Model of the correlation between flexible manufacturing systems and human resource sustainability (combined)

Table 3: Correlations between components of FSM and HRS

| Components of Flexible Manufacturing Systems | Other components | Computer control system | Inspection equipment | Handling and storage system | Workstations |
|----------------------------------------------|------------------|-------------------------|----------------------|-----------------------------|--------------|
| Human Resource Sustainability                | 0.928*           | 0.902*                  | 0.644*               | 0.833*                      | 0.841*       |

1. Workstations → HRS. The correlation is positive and significant ( $r = 0.841^*$ ,  $\alpha = 0.05$ ).
2. Handling & Storage Systems → HRS. The correlation is positive and significant ( $r = 0.833^*$ ,  $\alpha = 0.05$ ).
3. Inspection Equipment → HRS. The correlation is positive and significant ( $r = 0.644^*$ ,  $\alpha = 0.05$ ).
4. Computer Control Systems → HRS. The correlation is positive and significant ( $r = 0.902^*$ ,  $\alpha = 0.05$ ).
5. Other Components → HRS. The correlation is positive and significant ( $r = 0.928^*$ ,  $\alpha = 0.05$ ).

In summary, all five FMS components exhibit statistically significant positive associations with human resource sustainability; therefore, Sub-Hypothesis (A) is supported.

Accordingly, Sub-Hypothesis (A) of the first main hypothesis is accepted, confirming that each component of flexible manufacturing systems demonstrates a significant positive correlation with human resource sustainability.

#### Second main hypothesis

There is a significant effect of flexible manufacturing system components on the dimensions of human resource sustainability (overall) in the organization under study. To test this hypothesis, a Structural Equation Model (SEM) was specified and estimated (see Fig. 6). For the evaluation. Model fit indices and path estimates were examined to judge hypothesis support; the relevant test statistics and criteria are reported in Table 4. These results determine whether the second hypothesis is accepted or rejected.

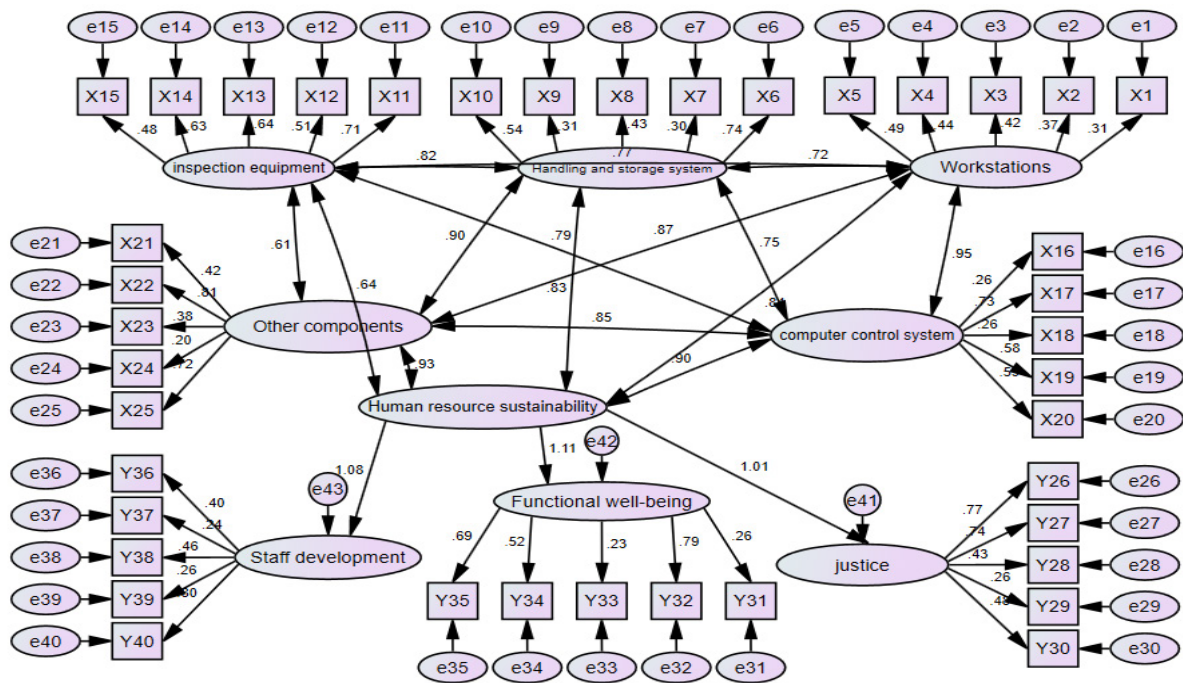


Fig. 4: A model of the correlation between the components of FSM (individually) and HRS

Table 4: Values of the analysis of H2 (combined).

| Influencing variable | Direction of effect | Variable affected by | Estimate | SRW   | Upper | Lower | P    |
|----------------------|---------------------|----------------------|----------|-------|-------|-------|------|
| FMS                  | →                   | HRS                  | 2.079    | 0.932 | 0.971 | 0.896 | 0.02 |

Table 4, compiled by the researchers from the soft-waBluere output—shows a direct, statistically significant effect of FMS dimensions on HRS. The Standardized Regression Weight (SRW) is 0.932, and the unstandardized coefficient (Estimate) is 2.079. This effect is significant given  $p = 0.02 < 0.05$ . The 95% confidence interval for the coefficient (0.896–0.971) excludes zero, further confirming the robustness of the effect. Accordingly, the second main hypothesis is accepted.

#### Sub-hypothesis (A) of the second main hypothesis

Each dimension of the flexible manufacturing system exerts a significant effect on human resource sustainability within the organization under study. To evaluate this sub-hypothesis, an SEM was specified and estimated (see Fig. 6). The corresponding fit in-

dices and path coefficients used to determine acceptance or rejection of the sub-hypothesis are reported in Table 5. These statistics provide the basis for judging the significance and direction of the effects from each FMS dimension to the HRS construct.

The SEM results confirm the significance of the model used to test Sub-Hypothesis (A) of the second main hypothesis. As shown in Table 5, the model exhibits positive fit indicators and high saturation (factor loading) values exceeding 45%, consistent with the acceptable thresholds (see Fig. 6). Examining the path estimates and their standard errors indicates that the largest effect among individual FMS components on human resource sustainability stems from the Computer Control System, suggesting that the organization prioritizes computerization and production-line automation to support long-term HRS. By contrast, the smallest

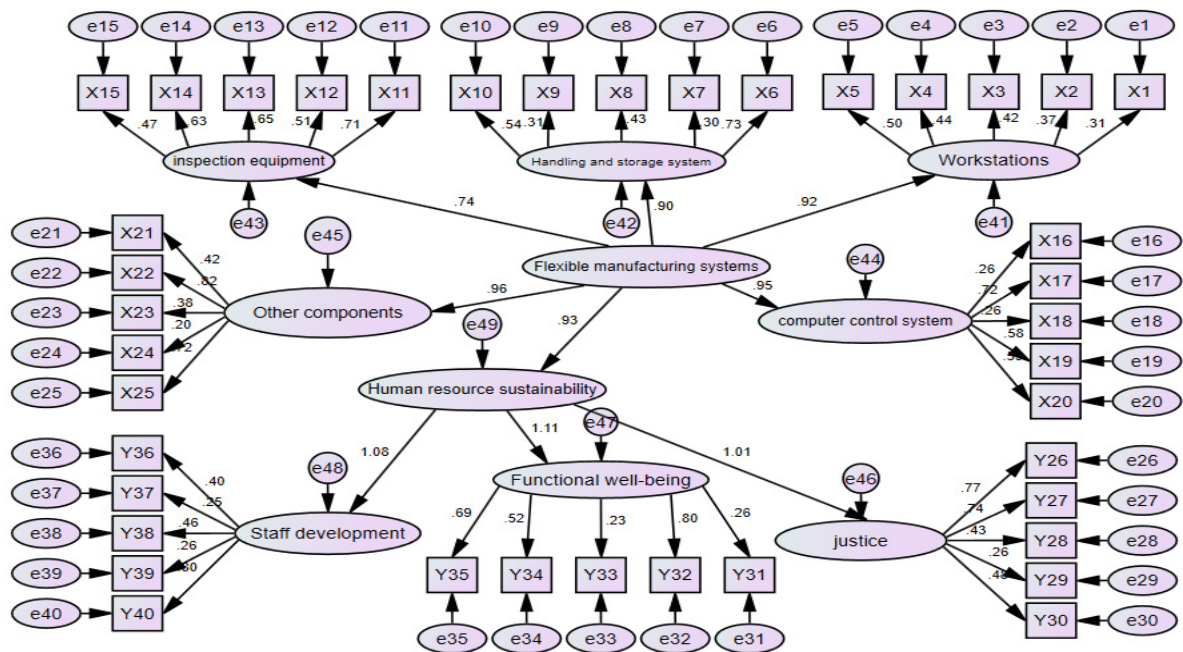


Fig. 5: Model of the influence relationships between the components of flexible manufacturing systems (together) on human resource sustainability

Table 5: Values of the H2

| Influencing variable        | Direction of effect | Variable affected by          | Estimate | SRW   | Upper | Lower | P    |
|-----------------------------|---------------------|-------------------------------|----------|-------|-------|-------|------|
| Workstations                | →                   | Human resource sustainability | 0.717    | 0.347 | 0.456 | ..... | 0.29 |
| Handling and storage system | →                   | Human resource sustainability | 1.000    | 0.601 | 0.763 | 0.415 | 0.04 |
| Inspection equipment        | →                   | Human resource sustainability | 1.114    | 0.515 | 0.145 | ..... | 0.02 |
| Computer control system     | →                   | Human resource sustainability | 5.460    | 1.189 | ..... | 0.673 | 0.00 |
| Other components            | →                   | Human resource sustainability | 0.003    | 0.003 | 2.218 | 0.902 | 0.99 |

effect is associated with Other Components, a result attributable to environmental turbulence, resource constraints, and adherence to legal and regulatory requirements that collectively limit the organization's ability to adopt ancillary technologies at pace. The critical ratio (C.R.) = 3.18 exceeds the reported critical values (1.96 and 1.99) at the stated significance levels (0.005 and 0.01, respectively), which are equivalent to the t-statistic benchmarks in conventional regression testing. Accordingly, Sub-Hypothesis (A) is accepted:

each FMS component exerts a significant effect on human resource sustainability within the organization under study. For future work, it can be summarized as follows, according to the proposed methods (Haller et al., 2025; Blecha et al., 2025; Blondheim, 2025):

- Prioritize Computer Control Systems, which allocate targeted funding for software and hardware upgrades (e.g., control platforms, HMIs, SCADA/MES links), with a staged rollout plan and ROI/KPI tracking (e.g., error rate, un-

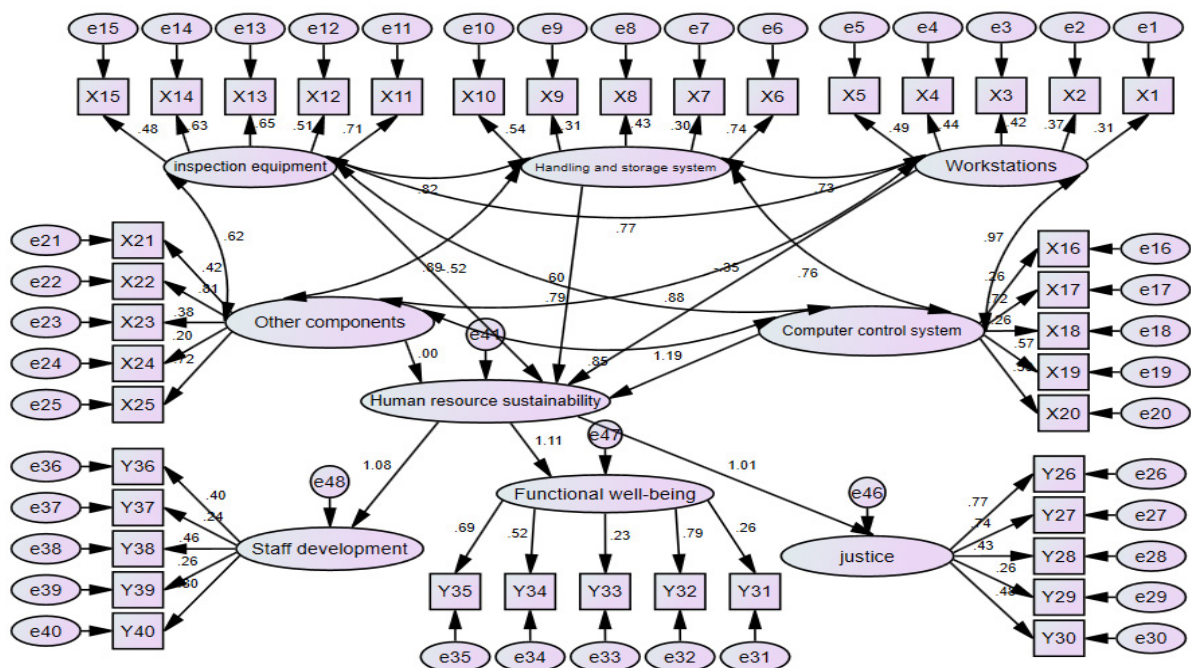


Fig. 6: Model of the influence relationships between the components of flexible manufacturing systems (individually) on human resource sustainability

- planned downtime).
- Capability Building is implementing structured training (initial + refresher) on FMS/CCS use, with competency checklists and certification; link completion to performance objectives.
- Modernize Handling & Storage, which upgrades AMHS elements (conveyors, AGVs, racking, sensors) to reduce manual handling, improve flow, and enhance safety; track outcomes via near-miss incidents, MTTR/MTBF, and throughput.
- Optimize Internal Workflows: map value streams for high-volume lines; remove bottlenecks, standardize work, and establish visual management. Monitor lead time, WIP, and OEE to verify gains.
- Environmental Scanning & Constraints Management conducts periodic internal-external analyses (e.g., SWOT/PESTLE) to identify opportunities and regulatory/resource constraints; integrates findings into annual capex and risk registers.
- Strategic Partnerships. Pursue vendor, academ-

- ic, and integrator partnerships to access expertise, pilot technologies, and share cost/benefit—especially for high-capex components.
- Advance Inspection Capability, which shifts toward automated/assisted inspection (e.g., CMM upgrades, in-line sensing, SPC dashboards) to reduce human error and accelerate feedback to operators.
- Integrated HRS–FMS Strategy, which develops a comprehensive HRS strategy explicitly linked to FMS design, deployment, and continuous improvement (not siloed by component). Include KPIs such as: lost-time injury frequency rate, ergonomic risk scores, training completion, engagement index, turnover, rework/scrap rate, and OEE.

Taken together, these results provide several empirical contributions. First, they offer rare evidence from the Iraqi pharmaceutical industry on how FMS components are related to human resource sustainability, a context that has received limited attention in prior research. Second, by showing that all five FMS

components are positively associated with HRS and that computer control systems exert the strongest standardized effect, the study identifies which technological investments are likely to yield the greatest sustainability benefits for employees. Third, the validated structural equation model integrates FMS and HRS into a single analytical framework that can be replicated or extended in future studies on sustainable manufacturing.

## CONCLUSIONS AND FUTURE WORK

*Workstations ↔ HRS:* The analysis shows a strong positive association between workstation design/functionality and HRS. Enhancing ergonomics and task design improves the work environment, reduces physical/psychological strain, raises job satisfaction, and lowers turnover.

*Handling & storage systems ↔ HRS:* There is a strong positive correlation between the efficiency of handling and storage systems and HRS. Better flow, reduced manual effort, and improved safety procedures lower occupational risk, strengthen employee health and safety, and increase productivity and satisfaction—thereby supporting HRS.

*Inspection equipment ↔ HRS:* Results indicate a moderately strong positive relationship. Accurate inspection tools raise product quality and reduce rework and errors, which eases time pressure and stress on employees and, in turn, supports HRS.

*Computer control systems ↔ HRS:* The correlation is very strong and positive. Effective computer control—through automation and reliable data—reduces repetitive tasks, improves operational accuracy, and enhances employee satisfaction, reinforcing HRS.

*Other components ↔ HRS:* A very strong positive correlation is observed. Supporting elements (e.g., advanced software, communications, infrastructure) enable system integration and better working conditions, reducing stressors and providing adequate operational support, thus advancing HRS.

*FMS as an Integrated System → HRS:* Collectively, FMS dimensions exert a direct, significant impact on HRS. Investment in FMS improves not only production efficiency but also the sustainability of the workforce by enhancing the work environment, mitigating risks, and increasing job satisfaction.

In summary, the results of the present study are broadly consistent with earlier work on sustainable HRM and organizational flexibility. Studies such as

Cherian and Farouk (2017), Stankeviciute and Savaneviciene (2018), and Lu *et al.*, (2023) report that human resource practices aligned with sustainability principles enhance employee well-being, commitment, and performance, which accords with our finding that higher levels of HRS are associated with better-designed FMS components. Similarly, research on flexibility and manufacturing systems (e.g., Kalogiannidis *et al.*, 2022; Kavaliauskiene *et al.*, 2022) emphasizes the strategic value of flexible technologies for building resilient organizations. By demonstrating that computer control systems and handling and storage systems show particularly strong links to human resource sustainability in a pharmaceutical setting, this study extends these insights to a new empirical context and highlights the human side of flexible manufacturing.

## AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. The authors performed data collection and analysis. All authors contributed to drafting and revising the manuscript and approved the final version.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the authors have acknowledged the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, which have been fully addressed.

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## ABBREVIATIONS (NOMENCLATURE)

|             |                                                         |
|-------------|---------------------------------------------------------|
| AMHS        | Automated Material Handling and Storage (System)        |
| CFA         | Confirmatory Factor Analysis                            |
| CI          | Confidence Interval                                     |
| CMM         | Coordinate Measuring Machine                            |
| CNC         | Computer Numerical Control                              |
| CCS         | Computer Control System                                 |
| C.R.        | Critical Ratio (SEM test statistic, $\approx t$ -value) |
| ERP         | Enterprise Resource Planning                            |
| FMS         | Flexible Manufacturing System(s)                        |
| HRS         | Human Resource Sustainability                           |
| HRM         | Human Resource Management                               |
| JIT         | Just-in-Time                                            |
| p (P-value) | Probability value (significance level)                  |
| PPC         | Production Planning and Control                         |
| r           | Pearson Correlation Coefficient                         |
| SEM         | Structural Equation Modeling                            |
| SLS         | Scale-Free Least Squares (SEM estimator)                |
| SRW         | Standardized Regression Weight                          |
| $\alpha$    | Significance Level (Type I error rate)                  |

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