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Research Paper

Designing and Developing a Knowledge-Based Human Resource Management Model in Research Organizations

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Abstract

Background & Purpose: In research organizations, human capital is regarded as the most important source of knowledge creation, innovation, and organizational performance. Accordingly, the effectiveness of human resource management in such organizations largely depends on the extent to which human resource policies and practices are aligned with the requirements of knowledge generation, development, sharing, utilization, and retention. Despite the growing importance of knowledge-based human resource management, there remains a need for a model that is tailored to the characteristics of research organizations. Therefore, this study aimed to design and develop a knowledge-based human resource management model for research organizations.

Methodology: In terms of purpose, this study was developmental-applied, and in terms of methodology, it employed a descriptive-survey design conducted in two stages. In the first stage, the Delphi method was used to identify and validate the dimensions and indicators of knowledge-based human resource management. The Delphi panel consisted of academic and organizational experts with relevant expertise and experience. In the second stage, managers, experts, and knowledge workers were surveyed to assess the current status of knowledge-based human resource management. Data were collected using a Delphi questionnaire in the first stage and a structured questionnaire in the second stage.

Findings: The results of the Delphi process led to the identification and validation of an integrated knowledge-based human resource management model comprising six dimensions and 59 indicators. These dimensions included human resource acquisition, human resource training and development, human resource utilization, performance appraisal, compensation, and human resource retention. The assessment of the current status also indicated that knowledge-based human resource management at the Niroo Research Institute was not at a desirable level across any of the six dimensions. This finding indicates that existing human resource practices have not yet been sufficiently aligned with the requirements of knowledge-based work and the characteristics of specialized and research-oriented human resources.

Conclusion: The proposed six-dimensional model can provide a comprehensive framework for aligning the core functions of human resource management with the requirements of research organizations. Applying this model can facilitate the targeted acquisition and development of specialized human capital, more effective utilization of knowledge workers' capabilities, establishment of appropriate performance appraisal and compensation systems, and ultimately enhancement of the organization's capacity to retain talent and organizational knowledge.

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Introduction

Contemporary society is transitioning from industrial models based primarily on physical labor toward a knowledge-based society in which knowledge, expertise, and human capabilities have become major sources of value creation and competitive advantage. According to the resource-based view, resources that are valuable, rare, and difficult to imitate can provide the basis for sustainable competitive advantage (Barney, 1991). Accordingly, knowledge, as one of the most important strategic resources, plays a critical role in developing distinctive capabilities and achieving organizational performance (Donnelly, 2019). This importance is even more pronounced in research organizations, whose core activities are centered on the generation, development, integration, and application of knowledge and whose major outputs include scientific and technological knowledge, innovation, and specialized capabilities.

In such organizations, knowledge workers are the primary carriers and producers of organizational knowledge. A substantial proportion of their tacit knowledge, experience, and problem-solving capabilities remains embedded in individuals and cannot be fully captured in organizational documents and databases. Therefore, the acquisition, development, utilization, appraisal, compensation, and retention of knowledge workers directly affect an organization's capacity to create and preserve knowledge. Human resource management (HRM) has consequently evolved from an administrative function into a strategic mechanism for managing human capital and organizational knowledge. HRM encompasses policies, practices, and systems that influence employees' behaviors, attitudes, and performance (Noe et al., 2000), including such core functions as human resource acquisition, maintenance, development, and utilization.

However, the distinctive nature of knowledge workers requires these functions to be designed differently from traditional HRM practices. Horwitz et al. (2003) emphasize the need for differentiated and modern HRM systems that correspond to the growing prevalence of knowledge-based work. Similarly, Redman and Wilkinson (2006) regard knowledge workers as a distinctive workforce requiring different managerial mechanisms. The mobility of highly skilled employees further increases the importance of retention, as employee turnover can not only impose substantial recruitment and replacement costs but also result in the loss of tacit knowledge and organizational experience.

From this perspective, moving from traditional HRM toward knowledge-based human resource management (KBHRM) represents a strategic necessity. Liu and Liu (2011) emphasize the need to align HRM practices with the requirements of knowledge-based work and highlight

the role of functions such as recruitment and selection, training and development, performance appraisal, and compensation in promoting knowledge creation and sharing. Haesli and Boxall (2005) likewise demonstrate that HRM can strengthen an organization's ability to exploit knowledge as a strategic resource. Accordingly, KBHRM can be understood as an approach in which HRM functions are systematically designed and integrated to develop human capital while simultaneously facilitating the creation, utilization, sharing, and retention of organizational knowledge.

This perspective is also consistent with the knowledge-based view of the firm. Grant (1996) conceptualizes organizations as institutions for producing, combining, integrating, and distributing knowledge and identifies knowledge as a major source of organizational value creation. Therefore, if knowledge constitutes a primary source of distinctive capabilities, managing the people who generate and develop that knowledge should occupy a central position in strategic management. Within this framework, KBHRM can serve as a link between human capital, knowledge, and organizational capabilities, transforming employees' individual knowledge into organizational capabilities through the integrated management of acquisition, development, utilization, performance appraisal, compensation, and retention in ways that reflect the nature of knowledge-intensive work.

The importance of this issue is particularly evident in the Niroo Research Institute, a specialized research organization in the water and electricity sector, where the fulfillment of research and technological missions depends heavily on the knowledge, expertise, creativity, and retention of specialized human resources. In such an organization, weaknesses in attracting specialized personnel, developing research capabilities, utilizing employees' knowledge capacities, implementing performance appraisal and compensation systems appropriate to research activities, or retaining talented employees may undermine the organization's capacity for knowledge creation and innovation. Consequently, the requirements of such an organization cannot be adequately addressed merely by transferring general HRM models; rather, a model specifically aligned with the characteristics of research organizations is required.

Accordingly, the central problem addressed in this study is the design of an integrated knowledge-based human resource management model tailored to the characteristics of research organizations—a model that identifies its key dimensions and indicators while also providing a basis for assessing the organization's current status and identifying gaps between the existing and desired conditions. Therefore, this study seeks to answer the following questions; What are the dimensions and

indicators of an appropriate knowledge-based human resource management model for research organizations?, and What is the current status of knowledge-based human resource management at the Niroo Research Institute based on the dimensions and indicators of the identified model?.

Literature Review

The transition from an industrial economy to a knowledge-based economy has fundamentally transformed the role of intangible resources, particularly knowledge, in value creation and organizational competitive advantage. According to the resource-based view, organizations can achieve sustainable competitive advantage when their resources and capabilities are valuable, rare, and difficult to imitate (Barney, 1991). Within this framework, knowledge and specialized human capital are regarded as among the most important strategic organizational resources because, unlike many physical resources, specialized knowledge and human expertise are not easily imitated or replaced. Donnelly (2019) likewise emphasizes the role of knowledge in creating competitive advantage and the importance of organizations' capabilities to acquire and effectively utilize knowledge. Therefore, in turbulent and knowledge-intensive environments, an organization's ability to manage its knowledge resources constitutes a major component of its capacity to achieve sustainable performance.

The knowledge-based view takes this argument a step further by placing knowledge at the center of organizational processes. From Grant's (1996) perspective, an organization is an institution for integrating the specialized knowledge of its members, with a substantial portion of organizational knowledge residing in individuals. Consequently, a fundamental organizational challenge is to develop mechanisms for coordinating and effectively utilizing individuals' specialized knowledge. This perspective highlights the importance of knowledge workers, who possess a significant proportion of organizational intellectual capital in the form of expertise, experience, skills, and tacit knowledge. Swart (2009) also emphasizes the distinctive characteristics of knowledge workers and the managerial challenges arising from the relationship between individual and organizational knowledge. Accordingly, knowledge-based organizations require mechanisms that go beyond traditional workforce control and management in order to transform individual knowledge into organizational capabilities.

This necessity is particularly evident in research organizations because their core activities are directly dependent on the generation, development, integration, and application of knowledge. Research employees are not merely implementers of organizational processes; they

are also producers and carriers of a substantial portion of organizational knowledge, much of which cannot be fully codified and stored. Consequently, the mobility or departure of knowledge workers may have consequences beyond the loss of an individual employee and may result in the loss of part of the organization's accumulated knowledge and experience. Research on knowledge-worker mobility also indicates that the relationship between the mobility of specialized employees and knowledge transfer constitutes an important issue in knowledge and human capital management (Ferreira et al., 2022). Furthermore, Horwitz et al. (2003) demonstrate that knowledge workers have distinctive characteristics and expectations and therefore require differentiated practices in areas such as recruitment, development, and retention.

Knowledge-Based Human Resource Management; Knowledge-based human resource management (KBHRM) has emerged in response to the limitations of traditional human resource management approaches in knowledge-intensive environments. In traditional approaches, human resources are primarily viewed in terms of meeting staffing requirements, controlling performance, and providing compensation and benefits. In knowledge-based environments, however, employees themselves constitute a substantial component of an organization's strategic capital. Accordingly, HR policies and practices should be designed not only to attract individuals with appropriate knowledge and capabilities but also to facilitate the development, utilization, sharing, and retention of their knowledge. Haesli and Boxall (2005) demonstrate a close relationship between knowledge management and HR strategies and argue that different knowledge management strategies can influence employee selection and retention. Similarly, Dörhöfer (2012) emphasizes the need to integrate knowledge management and human resource management and to reconsider traditional HRM principles in response to the requirements of knowledge-based organizations.

Accordingly, KBHRM can be conceptualized as an integrated set of HR policies and practices designed to manage human capital effectively and transform individual knowledge into organizational capabilities. Within this approach, functions such as recruitment and selection, training and development, human resource utilization, performance appraisal, compensation, and retention should be aligned with the nature of knowledge-based work. Research examining the relationship between HRM and knowledge-based performance also indicates that HR practices can influence knowledge-sharing behaviors and, ultimately, organizational knowledge-based performance by creating capabilities, motivation, and opportunities for employee participation (Wright et al., 2013). From this perspective, KBHRM does not simply mean adding knowledge-related components to traditional HRM; rather, it requires the

redesign and integration of HR functions based on the nature of knowledge and knowledge workers.

This approach is particularly important in research organizations because organizational quality and effectiveness depend heavily on their ability to attract specialized personnel, continuously develop their capabilities, provide opportunities for effective knowledge utilization, evaluate employees in accordance with the nature of research activities, provide compensation consistent with their value creation, and retain specialized talent. Recent studies on KBHRM also indicate that key operational areas of this approach include knowledge-based recruitment and selection, training and development, knowledge-based compensation, and performance appraisal, while the existing literature still requires further development regarding the dimensions and multidimensional structure of KBHRM. Therefore, a comprehensive model for research organizations should integrate the core HR functions in accordance with the requirements of knowledge creation, development, utilization, and retention. This perspective provides the theoretical foundation for the six-dimensional model proposed in the present study, comprising human resource acquisition, training and development, utilization, performance appraisal, compensation, and retention.

Empirical Background of Knowledge-Based Human Resource Management in Research Organizations

Empirical research on knowledge workers and knowledge-intensive organizations indicates that conventional human resource management practices need to be adapted to the distinctive characteristics of knowledge-intensive work. Horwitz et al. (2003), in an empirical study of knowledge-intensive firms in Singapore, examined HR strategies for attracting, motivating, and retaining knowledge workers. Their findings demonstrated that effective management of knowledge workers depends on distinctive bundles of HR practices rather than on isolated HR interventions. In particular, recruitment and attraction, employee development, competitive rewards, opportunities for advancement, autonomy, and retention-oriented practices emerged as important elements of managing knowledge workers. The study therefore provides empirical support for viewing human resource acquisition, training and development, compensation, and retention as interconnected dimensions of knowledge-based HRM.

Evidence from research and development environments further demonstrates the importance of HR practices for knowledge-intensive employees. Liu and Liu (2011), in an empirical study of R&D professionals in Taiwanese high-technology firms, examined the relationship between HR practices and individual knowledge-sharing behavior. Their findings showed that HR practices, including

performance appraisal and compensation-related practices, can influence employees' knowledge-sharing behavior through motivational and capability-related mechanisms. These findings are particularly relevant to research organizations because knowledge sharing is an essential component of research activity and organizational knowledge creation. Accordingly, performance appraisal and compensation should not be viewed merely as administrative HR functions; rather, they can be designed to reinforce knowledge-related behaviors and organizational objectives.

The importance of human resource utilization is also supported by empirical research on knowledge workers. Unlike routine employees, knowledge workers generally perform tasks that require professional expertise, problem solving, creativity, autonomy, and the application of specialized knowledge. Horwitz et al. (2003) found that autonomy and opportunities to exercise professional capabilities are important elements of effective knowledge-worker management. Similarly, research on knowledge workers' creativity has shown that individual characteristics and the social-organizational work environment significantly influence creative performance (Dul et al., 2011). These findings suggest that simply recruiting highly qualified employees is insufficient; organizations must also provide jobs, work environments, and organizational arrangements that allow employees to effectively utilize their knowledge and capabilities.

Human resource training and development represents another important dimension supported by empirical evidence. Knowledge-intensive work is characterized by continuous changes in technologies, professional knowledge, and problem-solving requirements. Consequently, the knowledge acquired at the time of recruitment cannot remain sufficient throughout an employee's career. Horwitz et al. (2003) identified career development and opportunities for professional growth among the practices associated with effective management of knowledge workers. Research on university scientists likewise demonstrates the importance of employment conditions and opportunities for the long-term development of research careers. In their study of 40 research scientists working in five university research centers in Ireland, McCarthy et al. (2014) found that contractual employment arrangements could restrict access to employment conditions and opportunities that are important for researchers' long-term professional success.

The empirical literature also provides a strong basis for considering human resource performance appraisal as a distinct dimension. Knowledge workers' performance is often multidimensional and may involve scientific output, innovation, problem solving, knowledge sharing, collaboration, and contribution to organizational capabilities. Liu

and Liu (2011) demonstrated the relevance of HR practices, including performance appraisal, to knowledge-sharing behavior among R&D professionals. In addition, the literature on knowledge-worker management emphasizes the need to align HR practices with the characteristics of knowledge work rather than applying standardized mechanisms designed for routine work. Thus, performance appraisal in research organizations should recognize the distinctive nature of scientific and knowledge-based contributions and should be connected to employee development and organizational learning.

Human resource compensation is similarly important because knowledge workers possess specialized and relatively scarce capabilities and may have substantial mobility across organizations. Horwitz et al. (2003) found that compensation and reward practices formed part of the HR bundles used to attract, motivate, and retain knowledge workers. Liu and Liu (2011) also demonstrated the relevance of HR practices to knowledge-sharing behavior among R&D professionals. These findings suggest that compensation systems in research organizations should extend beyond conventional salary structures and consider mechanisms that recognize individual and collective contributions, knowledge creation, research achievements, and other forms of value creation.

Finally, human resource retention is particularly critical in research organizations because employee turnover can involve the loss of both human capital and organizational knowledge. Lee and Maurer (1997), focusing specifically on knowledge workers and engineers, argued that retaining knowledge workers is critical to organizational well-being and examined how different HR functions can facilitate retention for different types of knowledge workers. Their framework explicitly connected standard HR functions with alternative turnover paths and demonstrated that retention strategies need to be aligned with the characteristics and career circumstances of knowledge workers. Similarly, research on university research scientists indicates that employment conditions can shape researchers' long-term opportunities and career prospects, highlighting the importance of stable and supportive employment arrangements for retaining scientific and technical human capital.

Taken together, the empirical evidence indicates that knowledge-based HRM in research and knowledge-intensive organizations is multidimensional rather than reducible to a single HR practice. Across the reviewed studies, six recurring areas can be identified: acquiring appropriate knowledge-based human capital, effectively utilizing employees' specialized capabilities, continuously developing their knowledge and competencies, evaluating their performance in accordance with the nature of knowledge work, providing appropriate compensation and rewards, and retaining valuable knowledge workers. Importantly,

prior studies have generally examined these practices either individually or as selected bundles of HR practices rather than developing and empirically validating an integrated six-dimensional model specifically for research organizations. This gap provides the rationale for subjecting the six dimensions to expert validation through the Delphi process in the present study.

Based on the empirical evidence presented above, six main dimensions were identified as the initial dimensions of knowledge-based human resource management in research organizations. The following table presents the initial framework derived from the empirical literature, which served as the basis for developing the questionnaire for the first round of the Delphi process.

Methodology

This study was conducted with the aim of developing the concept of knowledge-based human resource management (KBHRM) and designing and validating a model for knowledge-based human resource management in research organizations. In terms of purpose, the study was developmental-applied, and in terms of approach, it employed a combination of qualitative and quantitative methods. The research process consisted of two main stages. In the qualitative stage, the dimensions and indicators associated with knowledge-based human resource management were first identified through a review of documentary sources, including academic articles, books, and previous studies, and an initial conceptual model was developed. The model was then examined and refined using the Delphi technique in two rounds. In the quantitative stage, the final model was empirically validated using second-order confirmatory factor analysis (CFA) and structural equation modeling (SEM).

In the Delphi stage, the expert population consisted of 30 industrial experts and academic scholars in the field of management, selected based on their relevant expertise and experience in human resource management and research organizations. In the first Delphi round, based on the findings of the literature review, 71 initial indicators across six dimensions of knowledge-based human resource management—including human resource acquisition, utilization, training and development, performance appraisal, compensation, and retention—were developed and presented to the experts through a five-point Likert-scale questionnaire. At this stage, the mean, standard deviation, and importance rank of each indicator were calculated, and indicators with a mean score below 3.00 were eliminated. Suggestions proposed by the experts were also examined. Specifically, knowledge-worker motivation was proposed as a separate dimension by four experts and was therefore included for

further assessment in the second round. In addition, one new indicator in the retention dimension was proposed by seven experts and was added to the second-round assessment.

To assess the degree of agreement among the experts, Kendall's coefficient of concordance (Kendall's W) and the chi-square test were employed. In the first round, Kendall's W for the dimensions of the model was 0.72, whereas its value for the indicators was 0.368, indicating the need for further revision and a second Delphi round. Accordingly, indicators with mean scores below 3.00 were removed, while the indicators and suggestions proposed by the experts were reassessed in the second round. In the second round, the revised dimensions and indicators were presented to the same panel of 30 experts. At this stage, Kendall's W reached 0.91 for the dimensions and 0.84 for the indicators, indicating a high level of agreement. Given the satisfactory level of concordance and the non-significance of the chi-square test, an acceptable consensus among the experts was achieved and the Delphi process was terminated. Ultimately, six dimensions and 59 indicators were confirmed as the final components of knowledge-based human resource management. The proposed dimension of knowledge-worker motivation was not retained as an independent dimension because its mean score was 2.34 in the second round and it did not achieve the required level of agreement.

In the quantitative stage, the statistical population consisted of experts, supervisors, middle managers, and senior managers of the research institute, comprising a total of 140 individuals. The sample size was determined as 105 respondents using Cochran's formula. To increase the likelihood of obtaining the required effective sample size, 140 questionnaires were distributed, of which 105 valid questionnaires were ultimately collected and analyzed. Convenience sampling was employed. The data-collection instrument at this stage was a questionnaire developed based on the 59 final indicators identified through the Delphi process. The content validity of the questionnaire was assessed and refined based on the opinions of five academic experts, including the research supervisors, advisor, and other subject-matter experts.

To assess the reliability of the instrument, 30 questionnaires were administered in a pilot study prior to the main survey, and Cronbach's alpha coefficient was calculated. The Cronbach's alpha coefficient for the complete set of 59 items was 0.961, indicating a very high level of internal consistency and reliability.

For the analysis of the quantitative data, descriptive statistics and analytical tests, including the one-sample t-test, Friedman test, and regression analysis, were initially employed. Subsequently, second-order confirmatory factor analysis (CFA) was conducted using LISREL to examine the factorial structure of the model and assess the relationships

between the six dimensions and the higher-order construct of knowledge-based human resource management. The results indicated an acceptable fit for the second-order measurement model. Specifically, the RMSEA was 0.03, SRMR was 0.08, and the chi-square-to-degrees-of-freedom ratio was 1.10. In addition, the fit indices NFI = 0.90, NNFI = 0.97, IFI = 0.98, and CFI = 0.97 indicated an acceptable overall model fit. The standardized factor loadings were 0.99 for human resource compensation, 0.94 for human resource acquisition, 0.92 for human resource utilization, 0.92 for training and development, 0.89 for performance appraisal, and 0.44 for human resource retention. All relationships were statistically significant and therefore supported.

Overall, the research process comprised theoretical identification of the indicators, refinement and consensus building among experts through two Delphi rounds, development of the final six-dimensional model comprising 59 indicators, and empirical validation of the model using second-order confirmatory factor analysis. This methodological process ensured that the knowledge-based human resource management model was supported both by the theoretical literature and expert consensus and that its measurement structure was empirically examined within the target research organization.

Findings

The Delphi method was repeated in two rounds to reach final agreement. In the first round, variables identified from the literature were presented to the panel in questionnaire form, and Kendall's W coefficient of concordance was calculated. The Delphi process was repeated until Kendall's W for the items approached an acceptable level, indicating agreement among respondents. The details and results of each round are presented below.

First-round Delphi results: Based on a review of the literature and previous studies, a comprehensive table of dimensions and indicators of knowledge-based HRM in research organizations was extracted and used as the basis for developing the first survey questionnaire. Seventy-one simple measures were initially developed for the six dimensions, and a five-point Likert scale was specified. The first-round Delphi questionnaire is presented in Appendix 1, Appendix 3. The low end of the scale (option 5) indicated very low relevance, while the high end (option 1) indicated complete relevance. The results of the first Delphi questionnaire are presented in the following tables. These tables report the factor name, number of responses, mean, standard deviation, and importance ranking based on the mean. Thirty experts participated in this stage.

Table 1. First-round Delphi results: Dimensions of knowledge-based human resource management

	Dimension Number	Dimension	Number of Responses	Mean	Standard Deviation	Importance Based on Mean
Human resource management in research organizations	1	Human resource acquisition	30	4.90	0.652	1
	2	Human resource utilization	30	4.50	0.812	5
	3	Human resource training and development	30	4.85	0.702	3
	4	Human resource performance appraisal	30	4.23	0.673	6
	5	Human resource compensation	30	4.81	0.669	4
	6	Human resource retention	30	4.89	0.711	2
	7	Knowledge-worker motivation	Four experts proposed this dimension as a separate dimension.			

According to the first-round Delphi questionnaire, all dimensions of the research HRM model derived from the literature and theoretical foundations were fully supported by the Delphi panel. At this stage, four experts proposed employee motivation for knowledge workers as a separate dimension; this dimension was added for review in the second Delphi round. As shown in Table 1, all dimensions were ranked by their mean scores. The six dimensions were considered to have the strongest effects on knowledge-based HRM. The results of Kendall's W coefficient of concordance are presented in Table 2. Because the chi-square test was not statistically significant at the stated level, the results indicate agreement among panel members. In addition, the Kendall coefficient was above 0.50 and tended toward 1, indicating relatively strong agreement. The proposed employee-motivation dimension was therefore to be reviewed in the second round.

Table 2. Statistical results of the first Delphi round

N	30
Kendall's W(a)	0.72
Chi-Square	16.645
df	5
Asymp. Sig.	0.126

Table 3. First-round Delphi results for the human resource acquisition dimension

Human resource acquisition dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Sources of supply	Recruitment through relationships with reputable universities	30	4.69	0.77	2
Sources of supply	Recruitment through internal (specialized) personnel of the institute	30	4.37	0.81	7
Sources of supply	Recruitment through doctoral theses and student internships at the institute	30	4.26	0.80	11

Sources of supply	Recruitment through employment agencies (eliminated)	30	2.40	1.49	20
Sources of supply	Recruitment through the employment link on the institute website	30	3.10	1.01	15
Sources of supply	Recruitment through public calls (eliminated)	30	2.72	1.60	18
Recruitment strategy	Attracting specialists with multiple skills	30	4.78	0.59	1
Recruitment strategy	Attracting graduates with advanced academic degrees	30	4.56	0.80	4
Recruitment strategy	Hiring for the organization rather than for a specific job	30	4.28	0.71	10
Recruitment strategy	Recruiting when the organization needs the employee rather than simply filling the organizational ceiling	30	4.33	0.29	8
Employment process	General (psychological) interviews conducted by the institute's selection unit	30	4.31	0.73	9
Employment process	Specialized employment examinations (eliminated)	30	2.61	1.74	19
Employment process	Use of competency assessment centers for hiring	30	4.14	0.86	12
Employment process	Specialized interview by the relevant scientific-research group	30	4.39	0.85	6
Employment process	Emphasis on the researcher's scientific and research record	30	4.55	0.93	5
Employment process	Reducing recruitment-process duration; revised to facilitating hiring procedures	30	4.67	0.73	3
Type of employment	Formal and full-time employment	30	4.08	0.66	13
Type of employment	Contractual and full-time employment	30	3.51	0.59	14
Type of employment	Project-based employment (eliminated)	30	2.75	1.17	17
Type of employment	Part-time contractual and conditional employment (eliminated)	30	2.85	1.29	16

As shown in Table 3, all components were ranked according to their mean scores (importance-rank column). Components evaluated at or above the medium level were selected for the next Delphi round. Therefore, the first 15 components with the highest ranks and strongest effects on the knowledge-based human resource acquisition dimension were retained because all had means above 3. Five indicators were eliminated at this stage.

Table 4. First-round Delphi results for the human resource utilization dimension

Knowledge-based human resource utilization dimension					
Dimension	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Job description	Non-routine and creative jobs	30	4.67	0.70	3
Job description	Challenging and risk-bearing jobs	30	4.80	0.69	1
Job description	Exciting jobs (eliminated)	30	2.86	1.18	14
Job description	Jobs with high work autonomy	30	4.78	0.62	2
Job description	Highly important and prominent jobs	30	4.09	0.70	8
Job description	Jobs with high variety	30	3.98	0.83	10
Job requirements	Utilization based on work experience (eliminated)	30	2.65	1.56	15
Job requirements	Competency-based utilization	30	4.11	0.77	7
Job requirements	Utilization consistent with the individual's expertise (person-job fit)	30	4.19	0.61	5
Job requirements	Utilization based on the researcher's multiple abilities and skills	30	4.38	0.68	4
Utilization method	Individual utilization (eliminated)	30	2.98	1.09	13
Utilization method	Group and team-based utilization	30	4.06	0.54	9
Utilization method	Utilization in jobs with a defined career path	30	3.65	0.94	12
Utilization method	Utilization based on individual interest	30	3.76	0.82	11
Utilization method	Utilization consistent with organizational needs	30	4.18	0.86	6

As shown in Table 4, all components were ranked according to their mean scores (importance-rank column). Components evaluated at or above the medium level were selected for the next Delphi round. Thus, 12 of the 15 indicators with the highest ranks and strongest effects on the knowledge-based human resource utilization dimension were retained because all had means above 3. Three initial indicators were eliminated at this stage.

Table 5. First-round Delphi results for the training and development dimension

Knowledge-based human resource training and development dimension					
Dimension	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Training and development	Training based on researchers' views and needs	30	3.18	0.97	6

Training and development	Emphasis on academic in-service training (eliminated)	30	2.85	1.15	7
Training and development	Emphasis on cross-functional in-service training and participation in training courses	30	4.65	0.65	2
Training and development	Emphasis on job-rotation-based training	30	4.81	0.61	1
Training and development	Training through internships and collaboration on different institute projects	30	4.39	0.78	4
Training and development	Training and socialization through collaboration with a researcher before employment	30	4.10	0.84	5
Training and development	Training through providing a specialized library and scientific and specialized websites	30	4.43	0.69	3

As shown in Table 5, all components were ranked according to their mean scores (importance-rank column). Components evaluated at or above the medium level were selected for the next Delphi round. Therefore, six of the seven indicators with the highest ranks and strongest effects on the knowledge-based training and development dimension were retained because all had means above 3.

Table 6. First-round Delphi results for the performance appraisal dimension

Knowledge-based human resource performance appraisal dimension					
Dimension	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Performance appraisal	Evaluation based on standardized scientific and research activities	30	4.16	0.76	4
Performance appraisal	Evaluation by colleagues and same-discipline specialists	30	4.29	0.79	3
Performance appraisal	Evaluation aimed at guiding and advising the researcher (not punishment or fault-finding)	30	4.65	0.62	1
Performance appraisal	Bottom-up supervision	30	4.39	0.70	2
Performance appraisal	Periodic control at specified time intervals	30	3.11	0.94	5
Performance appraisal	Evaluation combining individual and team performance (eliminated)	30	2.85	1.54	6

As shown in Table 6, all components were ranked according to their mean scores (importance-rank column). Components evaluated at or above the medium level were selected for the next Delphi round. Therefore, five of the six indicators with the highest ranks and strongest effects on the knowledge-based performance appraisal dimension were retained because all had means above 3.

Table 7. First-round Delphi results for the compensation dimension

Knowledge-based human resource compensation dimension					
Dimension	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Wages and salary	Paying salary with greater emphasis on the employee rather than merely the job	30	4.11	0.83	5

Wages and salary	Monthly salary plus project-based pay (eliminated)	30	2.21	1.56	7
Wages and salary	Performance-based pay	30	4.09	0.71	6
Reward	Participation in cash profits from projects	30	4.21	0.61	3
Reward	Granting shares to successful researchers (eliminated)	30	2.67	0.68	8
Reward	Project-based cash bonus (team-based)	30	4.19	0.59	4
Reward	Individual and group recognition and appreciation	30	4.69	0.66	1
Reward	Membership in the board of trustees and the institute's think tank	30	4.49	0.56	2

As shown in Table 7, all components were ranked according to their mean scores (importance-rank column). Components evaluated at or above the medium level were selected for the next Delphi round. Therefore, six of the eight indicators with the highest ranks and strongest effects on the knowledge-based compensation dimension were retained because all had means above 3.

Table 8. First-round Delphi results for the retention and maintenance dimension

Knowledge-based human resource retention dimension					
Dimension	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Knowledge-worker retention	Creating an environment for individual knowledge development	30	4.89	0.58	1
Knowledge-worker retention	Participation in organizational decision making	30	4.68	0.55	3
Knowledge-worker retention	Designing a career path and organizational advancement	30	4.14	0.71	9
Knowledge-worker retention	Flexible and floating working hours	30	4.69	0.59	2
Knowledge-worker retention	Developing communication within work groups	30	4.39	0.72	4
Knowledge-worker retention	Freedom and autonomy in activities	30	4.19	0.81	7
Knowledge-worker retention	Participation in organizational business objectives	30	3.69	0.92	14
Knowledge-worker retention	Emphasis on participative leadership in managing the organization	30	4.06	0.81	10

Knowledge-worker retention	Emphasis on a hands-off leadership style in the researcher's specialized work area	30	3.87	0.91	12
Knowledge-worker retention	Workplace ergonomics and safety	30	3.79	1.06	13
Knowledge-worker retention	Providing special welfare facilities (organizational housing, sports facilities, transportation, etc.)	30	4.02	0.70	11
Knowledge-worker retention	Providing various health, retirement, life, and other insurance schemes	30	4.19	0.82	8
Knowledge-worker retention	Motivating employees through delegating special authority in the work area	30	3.59	0.91	15
Knowledge-worker retention	Respecting and preserving the social status of researchers	30	4.22	0.57	6
Knowledge-worker retention	Receiving support from senior managers	30	4.31	0.59	5
Knowledge-worker retention	Developing a special disciplinary system for researchers consistent with their status and position	A new indicator was added; seven experts proposed this indicator.	A new indicator was added; seven experts proposed this indicator.	A new indicator was added; seven experts proposed this indicator.	A new indicator was added; seven experts proposed this indicator.

The results of Kendall's W coefficient of concordance are presented in Table 9. Because the chi-square test was statistically significant at the stated level, the differences among mean ranks were significant. Since the concordance coefficient tended toward zero, the test needed to be repeated with revisions. Therefore, statements or variables with means below 3.0000 were to be removed from the survey. Accordingly, five indicators were removed from the next round.

Table 9. Statistical results of the first Delphi round

N	**30**
Kendall's W(a)	0.368
Chi-Square	126.972
df	70
Asymp. Sig.	0.000

Analysis of the Second-Round Delphi Results

The second round of the Delphi process was conducted to reassess the dimensions and indicators that had been retained or revised following the first round and to determine whether sufficient consensus had been achieved among the experts. The same panel of 30 experts participated in this round. Based on the results, all six dimensions identified in the literature—human resource acquisition, human resource utilization,

training and development, performance appraisal, compensation, and retention—received high mean scores and were confirmed by the expert panel. Although knowledge-worker motivation had been proposed as an additional dimension by four experts in the first round, it received a mean score of only 2.34 in the second round and was therefore excluded from the final model.

The results also demonstrated a substantial increase in the level of agreement among the experts. Kendall's coefficient of concordance for the dimensions increased to 0.91, while the corresponding chi-square test was not statistically significant ($\chi^2 = 16.972$, df = 6, p = 0.138), indicating that the differences in the rankings were not statistically significant and that a satisfactory level of consensus had been achieved. Therefore, no further Delphi round was considered necessary.

Table 10. First-stage Delphi results: Dimensions of knowledge-based human resource management

	Dimensions	Dimensions	Number of responses	Mean	Standard deviation	Importance based on mean	Importance based on mean
Human resource management in research organizations	1	Human resource acquisition	30	4.90	0.652	1	1
Human resource management in research organizations	2	Human resource utilization	30	4.50	0.812	5	5
Human resource management in research organizations	3	Human resource training and development	30	4.85	0.702	3	3
Human resource management in research organizations	4	Human resource performance appraisal	30	4.23	0.673	6	6
Human resource management in research organizations	5	Human resource compensation	30	4.81	0.669	4	4
Human resource management in research organizations	6	Human resource retention	30	4.89	0.711	2	2
Human resource management in research organizations	7	Knowledge-worker motivation	30	2.34	1.86	1.86	7

According to the second-round Delphi questionnaire, all dimensions of the HRM model derived from the literature and theoretical foundations were fully supported by the Delphi panel. At this stage, four experts proposed knowledge-worker motivation as a separate dimension; however, this dimension was not retained as a new dimension in the second round and was removed. As shown by the mean scores, the dimensions were ranked accordingly. All dimensions except motivation had high effects on knowledge-based HRM. The Kendall's W results are reported in Table 11. Because the chi-square test was not statistically significant at the stated level, the difference among mean ranks was not statistically significant and agreement existed among panel members. In addition, Kendall's W was above 0.50 and tended toward 1, indicating relatively strong agreement; therefore, the survey could be stopped.

Table 11. Statistical results of the first Delphi round

N	30
Kendall's W(a)	0.91
Chi-Square	16.972
df	6
Asymp. Sig.	0.138

Table 12. Second-round Delphi results for the dimensions of the research model

Knowledge-based human resource acquisition dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Sources of supply	Recruitment through relationships with reputable universities	30	4.22	0.81	8
Sources of supply	Recruitment through internal (specialized) personnel of the institute	30	4.35	0.89	6
Sources of supply	Recruitment through doctoral theses and student internships at the institute	30	4.65	0.72	3
Sources of supply	Recruitment through the employment link on the institute website	30	4.05	0.79	11
Recruitment strategy	Attracting specialists with multiple skills	30	4.75	0.44	1
Recruitment strategy	Attracting graduates with advanced academic degrees	30	4.55	0.76	4
Recruitment strategy	Hiring for the organization rather than for a specific job	30	3.71	1.05	14
Employment process	General (psychological) interviews conducted by the institute's selection unit	30	4.40	0.68	5
Employment process	Use of competency assessment centers for hiring	30	3.85	0.67	13
Employment process	Specialized interview by the relevant scientific-research group	30	4.30	0.80	7
Employment process	Emphasis on the researcher's scientific and research record	30	4.10	0.79	10
Employment process	Facilitating hiring procedures	30	3.90	0.92	12
Type of employment	Formal and full-time employment	30	4.74	0.93	2
Type of employment	Contractual and full-time employment	30	4.15	0.97	9
Knowledge-based human resource utilization dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Job description	Non-routine and creative jobs	30	4.78	0.560	1
Job description	Challenging and risk-bearing jobs	30	4.64	0.547	4
Job description	Jobs with high work autonomy	30	4.55	0.689	5
Job description	Highly important and prominent jobs	30	3.54	0.941	12

Job description	Jobs with high variety	30	4.08	0.564	10
Job requirements	Competency-based utilization	30	4.31	0.854	6
Job requirements	Utilization consistent with the individual's expertise (person-job fit)	30	4.10	0.65	9
Job requirements	Utilization based on the researcher's multiple abilities and skills	30	4.65	0.84	3
Utilization method	Group and team-based utilization	30	3.84	0.88	11
Utilization method	Utilization in jobs with a defined career path	30	4.20	0.79	8
Utilization method	Utilization based on individual interest	30	4.67	0.92	2
Utilization method	Utilization consistent with organizational needs	30	4.28	0.73	7
Knowledge-based human resource training and development dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Training and development	Training based on researchers' views and needs	30	4.18	0.87	4
Training and development	Emphasis on cross-functional in-service training and participation in training courses	30	4.29	0.70	3
Training and development	Emphasis on job-rotation-based training	30	4.87	0.74	1
Training and development	Training through internships and collaboration on different institute projects	30	4.51	0.55	2
Training and development	Training and socialization through collaboration with a researcher before employment	30	3.98	0.59	6
Training and development	Training through providing a specialized library and scientific and specialized websites	30	4.01	0.81	5
Knowledge-based human resource performance appraisal dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Performance appraisal	Evaluation based on standardized scientific and research activities	30	4.11	0.61	3
Performance appraisal	Evaluation by colleagues and same-discipline specialists	30	4.69	0.79	1
Performance appraisal	Evaluation aimed at guiding and advising the researcher (not punishment or fault-finding)	30	4.01	0.99	4
Performance appraisal	Bottom-up supervision	30	4.29	0.72	2
Performance appraisal	Periodic control at specified time intervals	30	3.96	1.01	5
Knowledge-based human resource compensation dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Wages and salary	Paying salary with greater emphasis on the employee rather than merely the job	30	4.50	0.88	2

Wages and salary	Performance-based pay	30	4.08	0.91	6
Reward	Participation in cash profits from projects	30	4.18	0.831	5
Reward	Project-based cash bonus (team-based)	30	4.43	0.67	4
Reward	Individual and group recognition and appreciation	30	4.44	0.84	3
Reward	Membership in the board of trustees and the institute's think tank	30	4.59	0.96	1
Knowledge-based human resource retention dimension					
-	Indicator	Number of responses	Mean	Standard deviation	Importance based on mean
Knowledge-worker utilization	Creating an environment for individual knowledge development	30	4.89	0.88	1
Knowledge-worker utilization	Participation in organizational decision making	30	4.68	0.65	3
Knowledge-worker utilization	Designing a career path and organizational advancement	30	4.14	0.81	9
Knowledge-worker utilization	Flexible and floating working hours	30	4.69	0.49	2
Knowledge-worker utilization	Developing communication within work groups	30	4.39	0.62	4
Knowledge-worker utilization	Freedom and autonomy in activities	30	4.19	0.51	7
Knowledge-worker utilization	Participation in organizational business objectives	30	3.69	0.62	15
Knowledge-worker utilization	Emphasis on participative leadership in managing the organization	30	4.06	0.82	10
Knowledge-worker utilization	Emphasis on a hands-off leadership style in the work area	30	3.87	0.71	13
Knowledge-worker utilization	Workplace ergonomics and safety	30	3.79	0.56	14
Knowledge-worker utilization	Providing special welfare facilities (organizational housing, sports facilities, transportation, etc.)	30	4.02	0.77	11
Knowledge-worker utilization	Providing various health, retirement, life, and other insurance schemes	30	4.19	0.86	8
Knowledge-worker utilization	Motivating employees through delegating special authority in the work area	30	3.59	0.72	16
Knowledge-worker utilization	Respecting and preserving the social status of researchers	30	4.22	0.55	6

Knowledge-worker utilization	Receiving support from senior managers	30	4.31	0.79	5
Knowledge-worker utilization	Developing a special disciplinary system for researchers consistent with their status and position	30	3.87	0.68	13

As shown in Table 12, all variables were ranked according to their mean scores. All variables had strong effects on the human resource management dimensions. The results of Kendall's W are presented in Table 13. Because the chi-square test was not statistically significant at the stated level, the differences among mean ranks were not statistically significant and agreement existed among panel members. In addition, Kendall's W in Table 13 was above 0.50 and tended toward 1, indicating relatively strong agreement; therefore, the survey could be stopped.

Table 13. Statistical results of the second Delphi round

N	30
Kendall's W(a)	0.84
Chi-Square	16.434
df	58
Asymp. Sig.	0.118

Based on the results obtained in the second Delphi round and the relatively high concordance coefficient, six main dimensions of knowledge-based HRM and 59 core indicators were ultimately confirmed and selected for developing the conceptual model, as follows:

Figure 1. Research Conceptual Model

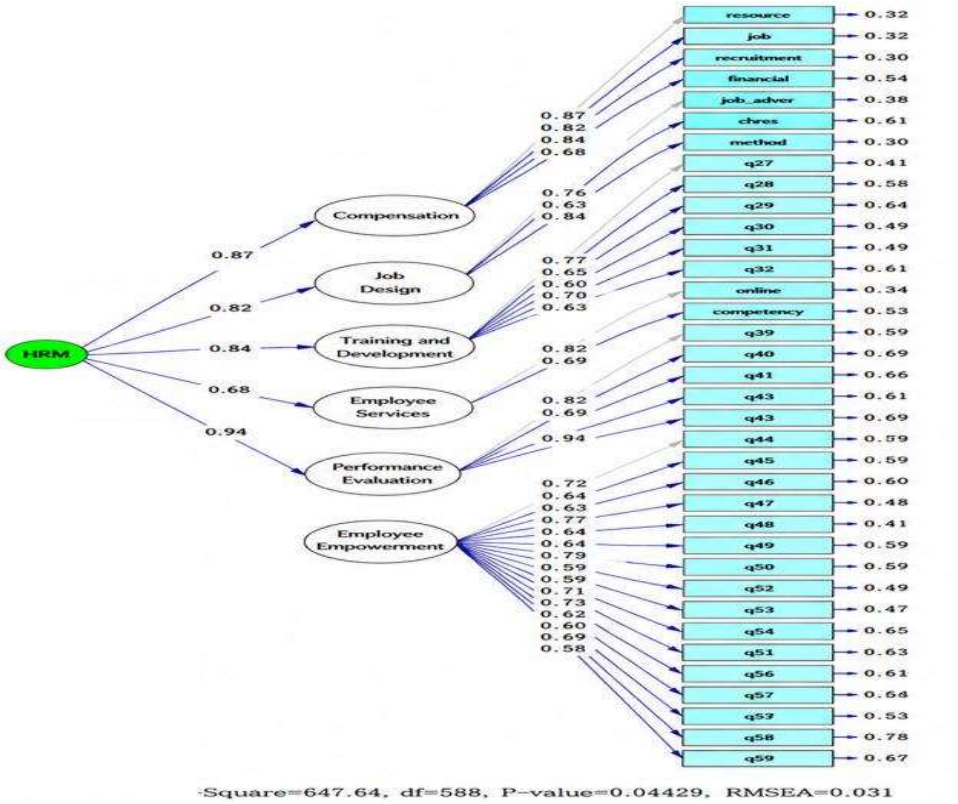

Figure 2. Second-order Confirmatory Factor Analysis of Knowledge-Based HRM (Standardized Coefficients)

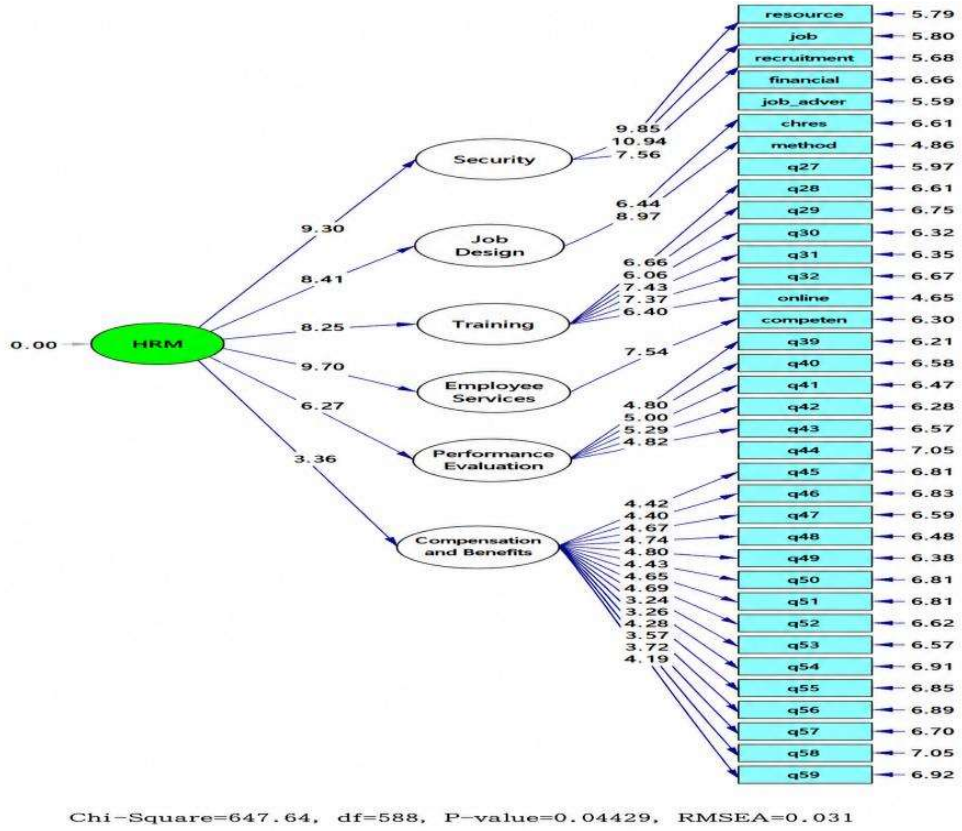

Figure 3. Second-order Confirmatory Factor Analysis of Knowledge-Based HRM (Significance Values)

The second-order measurement model seeks to explain first-order latent constructs through the final higher-order latent construct. The important fit indices were acceptable: RMSEA was 0.03 and below 0.08, SRMR was 0.08 and approximately acceptable, and the chi-square-to-degrees-of-freedom ratio was 1.10. The fit indices NFI = 0.90, NNFI = 0.97, IFI = 0.98, and CFI = 0.97 were also above 0.90. Therefore, the model demonstrated an acceptable overall fit. The results of this analysis are presented in Table 14.

Table 14. Results of the second-order confirmatory factor analysis of the knowledge-based human resource management model

Dimensions	Abbreviation	Standardized coefficient	Significance value	Relationship decision
Human resource acquisition	X1	0.94	9.30	Supported
Human resource utilization	X2	0.92	8.41	Supported
Human resource training and development	X3	0.92	8.25	Supported
Human resource compensation	X4	0.99	9.70	Supported
Human resource performance appraisal	X5	0.89	6.27	Supported
Human resource retention	X6	0.44	3.36	Supported

As shown in Table 14, the relationships between all variables and knowledge-based HRM are supported (significance values greater than 1.96). According to Table 14, human resource compensation has the highest standardized coefficient (0.99), followed by human resource acquisition (0.94), utilization and training and development (0.92 each), performance appraisal (0.89), and retention and maintenance (0.44). These dimensions therefore make the corresponding contributions to measuring knowledge-based HRM. The equation for these relationships is as follows:

$$HRM = .94X1 + .92X2 + .92X3 + .99X4 + .89X5 + .44X6$$

Discussion and Conclusion

The present study aimed to develop and validate an integrated knowledge-based human resource management (KBHRM) model for research organizations, with particular emphasis on the specific characteristics of knowledge workers and the knowledge-intensive nature of research activities. To achieve this objective, the study first examined the theoretical foundations and previous domestic and international research on knowledge workers and knowledge-based HRM. The Delphi technique was then employed in two rounds to identify, refine, and

validate the relevant dimensions and indicators. The results ultimately confirmed six dimensions and 59 indicators: human resource acquisition, human resource utilization, training and development, performance appraisal, compensation, and retention. The subsequent second-order confirmatory factor analysis provided empirical support for the proposed structure, demonstrating that the six dimensions constitute meaningful components of the higher-order construct of knowledge-based human resource management.

The Delphi findings are particularly important because they demonstrate that knowledge-worker motivation should not necessarily be treated as a separate and independent HRM dimension. Although four experts initially proposed motivation as an additional dimension, it failed to achieve sufficient agreement in the second round and was therefore excluded. This finding suggests that, in a knowledge-based HRM system, motivation may be embedded across several HR functions rather than operating as an isolated function. For example, meaningful work, autonomy, developmental opportunities, appropriate compensation, participation in decision-making, professional recognition, and career opportunities can collectively create the motivational conditions required by knowledge workers. Thus, the final six-dimensional structure provides a more functionally integrated representation of KBHRM than simply adding motivation as a separate HR function.

The findings are consistent with the resource-based and knowledge-based perspectives of the firm, which regard specialized human capital and knowledge as strategic resources capable of generating distinctive organizational capabilities (Barney, 1991; Grant, 1996). They are also broadly consistent with previous research emphasizing the distinctive requirements of managing knowledge workers and the strategic importance of HR practices in knowledge-intensive organizations (Horwitz et al., 2003; Haesli & Boxall, 2005). From this perspective, the contribution of the present study is not merely the identification of individual HR practices; rather, it demonstrates the need to integrate the principal HR functions around the characteristics of knowledge-intensive work. Such integration can enable research organizations to move from conventional personnel administration toward strategic management of human and knowledge capital.

The results of the second-order confirmatory factor analysis further strengthen this argument. All six dimensions had statistically significant relationships with the higher-order KBHRM construct, while the overall measurement model demonstrated acceptable fit. The standardized

coefficients were highest for compensation (0.99), followed by human resource acquisition (0.94), utilization (0.92), training and development (0.92), performance appraisal (0.89), and retention (0.44). These findings indicate that although all six dimensions contribute significantly to KBHRM, their relative contributions are not identical. In particular, the very high loading of compensation suggests that the way research organizations recognize and reward knowledge workers is closely associated with the overall effectiveness of a knowledge-based HRM system. This finding is important because knowledge workers often possess scarce and specialized capabilities and may evaluate organizational employment relationships not only in terms of financial rewards but also in terms of professional recognition, opportunities for influence, and the perceived value assigned to their expertise.

The importance of human resource acquisition, which showed the second-highest standardized coefficient, highlights the fact that KBHRM begins before employees enter the organization. Research organizations cannot compensate for inappropriate recruitment through subsequent HR interventions. The Delphi results emphasized attracting multidisciplinary specialists, recruiting highly educated personnel, establishing relationships with reputable universities, considering scientific and research records, and facilitating recruitment procedures. These findings are consistent with Horwitz et al. (2003), who emphasize differentiated HR practices for knowledge workers, and with Haesli and Boxall (2005), who highlight the strategic relationship between HR practices and knowledge management. For a research organization such as the Niroo Research Institute, the ability to attract researchers with advanced knowledge and multiple capabilities is therefore a prerequisite for strengthening scientific production, technological innovation, and the development of emerging fields such as renewable and green energy.

A particularly important practical implication concerns the university–research organization interface. The findings suggest that the Niroo Research Institute can move beyond conventional recruitment by establishing systematic relationships with reputable universities and identifying high-potential doctoral students in strategically important fields. Such relationships could involve jointly defining research topics aligned with organizational needs, providing research opportunities, evaluating students' scientific capabilities, and creating pathways for their subsequent employment. This approach would transform recruitment from a reactive process based on immediate vacancies into a strategic talent pipeline. In this way, the organization could identify and develop

potential knowledge workers before the formal recruitment stage and reduce the risk of losing highly qualified specialists to competing organizations.

The results concerning human resource utilization, which had a standardized coefficient of 0.92, also indicate that recruiting highly qualified knowledge workers is insufficient unless their capabilities are effectively deployed. The Delphi findings emphasized creative and non-routine jobs, challenging assignments, autonomy, competency-based utilization, person-job fit, use of multiple skills, attention to individual interests, and alignment with organizational requirements. These findings reinforce the argument that knowledge workers cannot be managed effectively through rigid job designs and narrowly defined roles. Their expertise should instead be connected to challenging assignments, opportunities for autonomy, interdisciplinary collaboration, and tasks that allow them to apply their full range of capabilities. This interpretation is consistent with research emphasizing the distinctive characteristics and management requirements of knowledge workers (Horwitz et al., 2003; Swart, 2009).

The training and development dimension also emerged as a major component of KBHRM, with a standardized coefficient of 0.92. The final indicators emphasize job rotation, cross-functional training, participation in different organizational projects, training based on researchers' needs, and access to specialized scientific resources. These findings indicate that professional development in research organizations should not be restricted to conventional classroom-based training. Instead, learning should be integrated with research projects, interdisciplinary collaboration, job rotation, scientific networks, and access to current knowledge resources. Such an approach can simultaneously enhance individual competencies and facilitate the conversion of individual knowledge into organizational knowledge.

The performance appraisal dimension, with a standardized coefficient of 0.89, also requires reconsideration in research organizations. The Delphi results particularly emphasized evaluation by colleagues and disciplinary specialists, assessment based on standardized scientific and research activities, developmental rather than punitive evaluation, and bottom-up supervision. These findings suggest that conventional performance appraisal systems based primarily on managerial judgment may be inappropriate for knowledge-intensive work. Since the quality and value of research outputs cannot always be assessed through short-term or purely quantitative indicators, evaluation

should incorporate professional peer judgment and developmental feedback. In this respect, the findings are consistent with the broader literature emphasizing the importance of appropriate performance-management systems for improving employee contribution and organizational effectiveness (DeNisi & Pritchard, 2006).

The retention dimension, despite having the lowest standardized coefficient among the six dimensions (0.44), remains an important and statistically significant component of KBHRM. Its lower coefficient should therefore not be interpreted as indicating that retention is unimportant. Rather, it may suggest that retention is partly an outcome of the quality of other HR functions. The Delphi results identify several mechanisms for retaining knowledge workers, including opportunities for individual knowledge development, participation in organizational decision-making, flexible working hours, career advancement, professional autonomy, communication within work groups, recognition of researchers' professional status, senior management support, welfare and insurance benefits, and an appropriate disciplinary system. This finding is consistent with the literature emphasizing the mobility of knowledge workers and the organizational risks associated with losing specialized human capital (Lee & Maurer, 1997; Horwitz et al., 2003).

Taken together, the findings suggest that KBHRM should be understood as an integrated system rather than a collection of independent HR practices. The six dimensions form an interconnected architecture in which acquisition provides access to appropriate human capital; utilization converts individual capabilities into organizational contributions; training and development continuously renew those capabilities; performance appraisal directs and improves their application; compensation recognizes and reinforces value creation; and retention protects accumulated human and organizational knowledge. Accordingly, weakness in one dimension can undermine the effectiveness of the others. For research organizations, the strategic objective should therefore be to establish consistency and alignment among these six functions rather than improving each function in isolation.

From an organizational perspective, the findings provide several implications for the Niroo Research Institute. First, recruitment should become more knowledge-intensive, proactive, and talent-oriented, with greater use of relationships with reputable universities, doctoral programs, scientific networks, and professional platforms. Second, recruitment procedures should be simplified and accelerated because highly specialized knowledge workers are subject to competition among

organizations, and lengthy administrative processes may result in losing desirable candidates. Third, selection should emphasize multidimensional and multidisciplinary capabilities, rather than focusing exclusively on narrow job-specific qualifications. Fourth, the organization should strengthen stable and appropriate employment arrangements where organizational regulations permit, because perceived employment insecurity may undermine employees' willingness to invest their knowledge and long-term commitment in the organization.

More broadly, the institute should develop a strategic knowledge-worker pipeline by identifying high-potential researchers at universities, engaging them in research projects and scientific committees, aligning doctoral research with organizational priorities, and establishing structured pathways from academic development to organizational employment. Such a mechanism can reduce dependence on reactive recruitment and simultaneously strengthen the institute's access to emerging scientific talent. In addition, the institute should redesign jobs around autonomy, creativity, complexity, and interdisciplinary collaboration; establish developmental and peer-based performance appraisal; expand project-based and competency-oriented learning; and create compensation and recognition mechanisms that reflect both individual and collective knowledge creation.

In conclusion, the present study demonstrates that an effective knowledge-based HRM system in research organizations requires a fundamental shift from conventional personnel administration toward strategic management of knowledge-intensive human capital. The validated model, consisting of six dimensions and 59 indicators, provides an integrated framework for this transition. Its principal value lies in connecting the major HR functions to the specific requirements of knowledge workers and research organizations. The model can therefore serve as a basis for diagnosing existing HR practices, identifying organizational gaps, prioritizing improvement initiatives, and designing HR policies that support knowledge creation, innovation, organizational learning, and the retention of critical expertise. For the Niroo Research Institute, implementing the model can ultimately strengthen its ability to attract scarce scientific talent, convert individual expertise into organizational capabilities, and sustain its research and technological mission in an increasingly knowledge-intensive environment.

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Conflict of Interest

The author(s) declare that there is no conflict of interest regarding the publication of this article. Furthermore, all relevant ethical considerations, including plagiarism, informed consent, research misconduct, data fabrication, and duplicate or multiple publication and submission, were observed by the authors.

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