KUDEAKETA AURRERATUA EUSKALIT GESTIÓN AVANZADA

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INSTITUTO VASCO DE LA MUJER

Erakunde autonomiaduna EUSKO JAURLARITZA — Organismo Autónomo del GOBIERNO VASCO

BUENAS PRÁCTICAS DE IGUALDAD EN LA GESTIÓN

TÍTULO DE LA PRÁCTICA DE IGUALDAD EN LA GESTIÓN: El valor del talento atendiendo al criterio de equidad interna.

OBJETIVOS QUE PERSIGUE: El desarrollo de un predictor salarial que permita la consecución de la equidad interna, que es un elemento crítico que afecta directamente a la motivación del personal, y ayude a la toma de decisiones a los órganos decisores de la materia.

ENTIDAD RESPONSABLE: Fundación Centro de Tecnologías de Interacción Visual y Comunicaciones Vicomtech

Nº DE TRABAJADORAS: 75 **Porcentaje de mujeres sobre el total de la plantilla:** 32,89%

Nº DE TRABAJADORES: 153 **Porcentaje de hombres sobre el total de la plantilla:** 67,11%

WEB: www.vicomtech.org

OTRAS ENTIDADES PARTICIPANTES EN LA BUENA PRACTICA:

FECHA DE COMIENZO: 2021

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PALABRAS CLAVE: Los 5 conceptos con los que más relación tiene la práctica son los siguientes:			
	Estrategia		Empleabilidad
X	**Personas**		Sector Masculinizado
	Alianzas		Reducción de Jornada
	Proveeduría		Permisos
	Responsabilidad Social corporativa		Maternidad y paternidad
	Modelo de Gestión		Conciliación corresponsable
	Transversal		Teletrabajo
X	**Cualitativo y cuantitativo**		Organización del tiempo y del espacio
	Gestión Sistemática o proceso		Cuidados y sostenibilidad de la vida
	Diagnóstico		Seguridad, Salud y Bienestar
X	**Plan para la igualdad**		Atención a la clientela/personas usuarias
X	**Estudios y análisis de género**		Protocolo de Acoso Sexual y por razón de sexo
	Integración en la estrategia		Condiciones laborales
	Feminicidio	**X**	**Política retributiva**

	Violencia de género		Clasificación profesional
	Anticipación del riesgo		Techo de cristal
	Comunicación Interna		Liderazgo
	Comunicación externa		Participación
	Comunicación no sexista		Interseccionalidad, Diversidad
	Transparencia		Perspectiva de Género
	Publicidad		Visibilización de mujeres referentes
	Días internacionales: campaña 22F, 8M, 25N		Autodefensa feminista
	Formación y Sensibilización		Empoderamiento
	STEAM		Políticas LGTBIQ+
	Mentorazgo		Masculinidades igualitarias
	Selección de personas y Promoción interna		Mujeres migrantes
			Intervención Social

SECTOR DE LA ORGANIZACIÓN:

	Educación
	Industria y servicios
X	**Otros**
	Salud
	Servicios públicos / Administración pública
	Servicios sociales

DESCRIPCIÓN:

Una vez seleccionadas las variables (ver Figura 1) por las que se rigen la carrera profesional y la evaluación de desempeño de las personas empleadas (en este caso personas investigadoras) se configura un predictor basado en aprendizaje automático para la evaluación del valor interno del talento de la organización validadora y para evaluar los criterios salariales ya determinados. El estudio asume, por tanto, el diseño y desarrollo de un predictor salarial basado en la inteligencia artificial para ayudar a determinar el valor interno de las personas empleadas y garantizar la equidad interna en la organización.

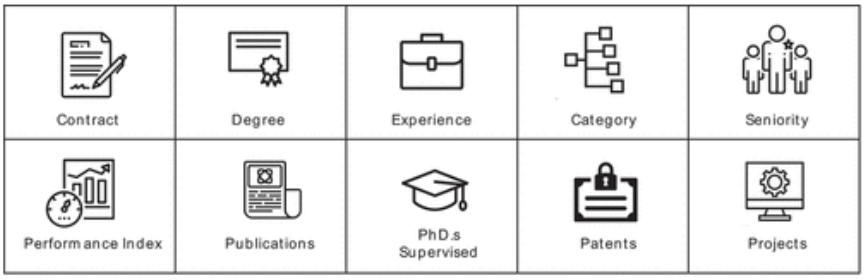

Figura 1: Variables determinantes del salario en la organización validadora.

Se ha implementado y validado el método, basado en el predictor, con 273 personas empleadas y más de 110 captaciones de talento desde el 2021 hasta la fecha.

Para este estudio se ha realizado el estado de la cuestión, basado en las diferentes metodologías salariales y en los sesgos humanos como de la Inteligencia Artificial. Esta revisión ha servido para realizar un desarrollo correcto de la herramienta por un lado y por otro para observar que mientras la mayoría de las entidades establecen variables para la evaluación de los puestos de trabajo, así como los incrementos salariales del personal por su contribución a la organización, sólo unas pocas utilizan herramientas que ayuden a una compensación equitativa interna. Esta herramienta aporta mucho valor en organizaciones medianas-grandes donde las personas que deciden las políticas salariales no pueden conocer de primera mano el rendimiento y desempeño de las personas empleadas, así como en las organizaciones donde las metodologías de desempeño se basan en variables o criterios objetivos.

ASPECTOS INNOVADORES:

El método presentado ayuda a minimizar la subjetividad de los órganos de toma de decisiones y garantiza la coherencia en la equidad interna en toda la organización. A su vez, permite una toma de decisión eficiente y efectiva. La práctica que se expone tiene en su haber dos artículos científicos, uno en Congreso y otro en revista científica de alto impacto (Q2, JCR). A su vez, la tecnología en la que se basa es vanguardista y las estrategias de validación en las que se ha basado el equipo del proyecto son novedosas. Otro aspecto innovador es el equipo de desarrollo de la herramienta, donde han participado personas del ámbito de Recursos Humanos, así como expertos en Inteligencia de Datos.

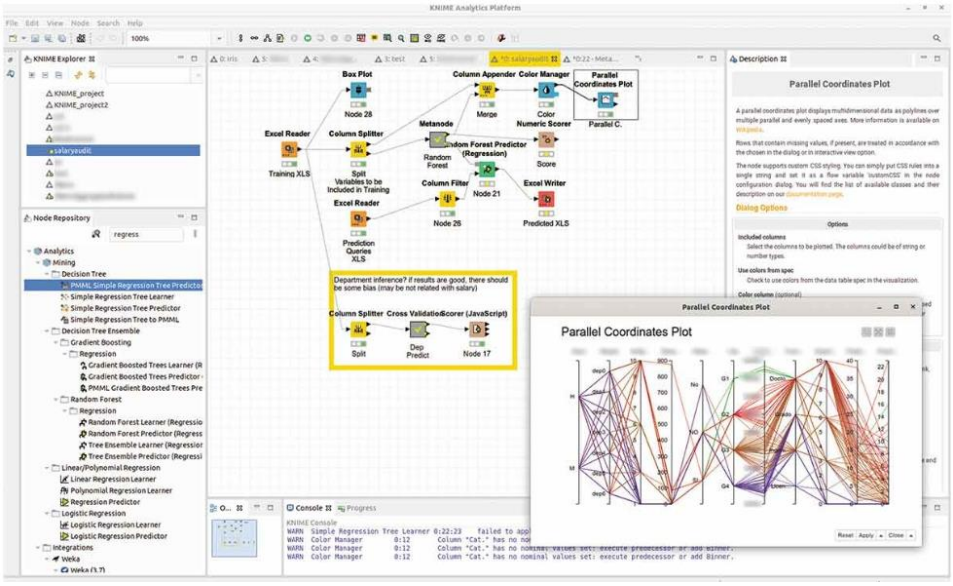

Figura 2: Tecnología utilizada, Knime.

RESULTADOS (impactos positivos o reducción de efectos negativos):

- Este método es más preciso que una valoración de puestos dado que permite realizar una valoración a cada persona.
- Es un método basado en un trabajo de objetividad de criterios y variables previo, donde la IA puede aprender con datos ya contrastados previamente.
- Este método minimiza la subjetividad de los órganos de decisión y asegura la equidad interna salarial de la organización, lo cual apoya la igualdad y la no discriminación de las personas.

INTEGRADA EN LA GESTION: Vicomtech dispone de un Sistema de Gestión Integral y este predictor está integrado en la parte del proceso de Personas del mismo. La gestión de personas en el centro se basa en el modelo de gestión basado en la metodología People CMM® (Capability Maturity Model) de la Universidad Carnegie Mellon. Este Modelo, se construye en base a todas las prácticas de Dirección de Personas existentes en el Centro. Cabe citar que este trabajo ha sido posible gracias al sistema de carreras profesionales y evaluación de desempeño realizado previamente donde se determinan las variables de evaluación de las personas empleadas. A este respecto existen dos artículos científicos que se exponen en la documentación relacionada.

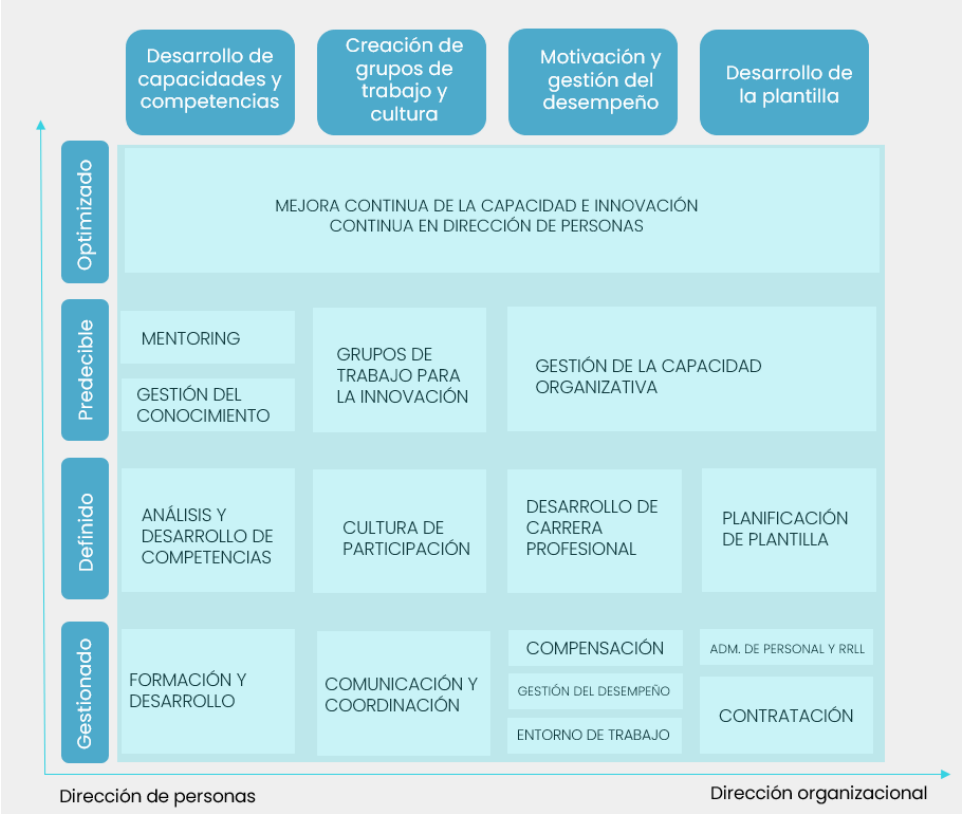

Figura 3: People CMM.

EFECTIVA Y EFICIENTE: Se requiere de un equipo multidisciplinar para poder desarrollar la herramienta, en concreto, personas del ámbito de Recursos Humanos y de Ciencia de Datos. La inversión realizada se amortiza en cada captación de personal, así como en las revisiones salariales dado que es factible hacerlo para muchas personas (práctica imposible sin esta herramienta) y la toma de decisión es más rápida con una herramienta tecnológica que te permite visualizar cada caso con respecto a los demás, como es el predictor.

PARTICIPACIÓN Y ALCANCE DE LA PRÁCTICA: En la toma de decisiones participa la Dirección del centro y se aplica en las captaciones de personas así como en las revisiones salariales, como herramienta tecnológica de apoyo.

DOCUMENTADA: Esta práctica ha sido expuesta en el Congreso R&D Management 2022 en Trento donde se aprobó el artículo científico que la explica, así como en la revista científica Applied Artificial Intelligence. El artículo se publicó en noviembre de 2022. Este hecho evidencia la novedad de la práctica. El artículo se incluye en la documentación relacionada.

FACTORES DE ÉXITO: El mayor factor de éxito es la efectividad contrastada y validada de la herramienta, la cual lleva dos años en uso y por tanto estamos ante un caso real y no un escenario hipotético. La herramienta sirve para garantizar la equidad, la igualdad y la no discriminación dado que así está entrenada. Esta práctica no se hubiera podido llevar a cabo sin el entendimiento entre las personas profesionales en el ámbito de Recursos Humanos y las de Ciencia de Datos, donde la multidisciplinariedad cobra valor. Todos los años se realiza una encuesta de satisfacción en la organización donde se incluyen preguntas de la política salarial para poder mejorar aspectos del propio paquete de compensación del centro y por tanto, se hace partícipe a todas las personas de cada práctica implementada.

TRANSFERIBILIDAD:

Este modelo puede ser implementado en otras organizaciones similares. El método presentado puede llevar a las organizaciones a una toma de decisiones más objetiva y mayores logros de las políticas salariales establecidas. Este método puede ser especialmente útil cuando los esfuerzos y los méritos son difíciles de medir, como es en el caso de las organizaciones de I+D que son intensivas en conocimiento, así como en organizaciones medianas-grandes donde los responsables de las decisiones salariares no pueden conocer el desempeño de cada empleado.

APRENDIZAJE:

Las principales lecciones aprendidas son las siguientes:

- Es muy importante desarrollar factores determinantes clave o variables para los salarios de una organización y deben ser transparentes y aceptables para las personas empleadas. Dado que pueden compararse entre sí, las organizaciones deben enfocar su comparación en términos de variables determinantes clave. El predictor funciona correctamente en términos de consistencia entre los factores “resultados por persona empleada” e “importe del salario”.
- Una cultura de Gestión de Recursos Humanos basada en datos es crucial para que la organización comience a trabajar en IA y logre la aceptación de las personas empleadas.
- Las personas son más que un número de logros e indicadores, ya que podría suceder que el predictor ignore algunos activos intangibles o variables. En consecuencia, el predictor debe ser una herramienta para ayudar en la toma de decisiones en lugar de tomar decisiones por sí mismo. El predictor debe revisarse cada año para evaluar si funciona correctamente y mejorarlo.
- Las personas que diseñan el predictor y los equipos de creación son cruciales para lograr una herramienta exitosa. Su conocimiento, colaboración y buen entendimiento, así como su compromiso para desarrollar un predictor justo, son muy importantes.

MATERIAL QUE ACREDITE LA PRÁCTICA: A continuación, se facilitan anexos con ejemplos que ilustran lo descrito anteriormente.

- Publicaciones científicas:
    - Loyarte-López, E. and García_olaizola, I. (2022): Machine Learning Based Method for Deciding Internal Value of Talent. Applied Artificial Intelligence. https://doi.org/10.1080/08839514.2022.2151160.

    - Loyarte-López, E. et al. (2020): Enhancing Researchers' Performance by Building Commitment to Organizational Results. Research-Technology Management. https://doi.org/10.1080/08956308.2020.1707010.

    - Loyarte-López, E. et al. (2020): Sustainable career development for R&D professionals: Applying a career development system in Basque Country. International Journal of Innovation Studies. https://doi.org/10.1016/j.ijis.2020.03.002.
- Presentación realizada en el Congreso R&D Management en Trento, 2022.

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Machine Learning Based Method for Deciding Internal Value of Talent

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Machine Learning Based Method for Deciding Internal Value of Talent

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ABSTRACT

This paper presents a machine-learning-based method for evaluating the internal value of talent in any organization and for evaluating the salary criteria. The study assumes the design and development of a salary predictor, based on artificial intelligence technologies, to help determine the internal value of employees and guarantee internal equity in the organization. The aim of the study is to achieve internal equity, which is a critical element a that directly affects employees' motivation. We implemented and validated the method with 130 employees and more than 70 talent acquisition cases with a Basque technology research organization during the years 2021 and 2022. The proposed method is based on statistical data assessment and machine-learning-based regression. We found that while most organizations have established variables for job evaluation as well as salary increments for staff according to their contribution to the organization, only a few employ tools to support equitable internal compensation. This study presents a successful real case of artificial intelligence applications where machine learning techniques help managers make the most equitable and least biased salary decisions possible, based on data.

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Introduction

In current times, knowledge-intensive organizations that base their business on highly qualified professionals and digital profiles need to have a highly productive human resources (HR) department, given the lack of talent in the market and high staff turnover. In this regard, these departments need to introduce technology into their processes and automate their organizational tasks to increase agility in processes such as recruitment, career development, performance evaluations, training, and employee compensation management (Sipahi and Artantaş 2022).

Artificial intelligence (AI) has aspects applicable to different disciplines and sectors, including HR processes (Somayya, Holmukhe, and Kumar Jaiswal 2019), and provides tools to help in decision making. Important challenges, such as evaluating the value of talent in an organization and achieving internal equity in the salary aspect, are achievable thanks to AI and machine-learning

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technologies. That is, crucial aspects for the organization can be addressed using AI approaches to help employees and the organization achieve better performance (Sowa and Przegalinska 2020).

Pay equity is a critical issue for organizations. This is confirmed by existing literature that aims to quantify and create fair tools to assess human resources. Given the latest European Commission legislation regarding gender equality (European Commission 2014, 2021), equity is a critical element that directly affects the motivation of the staff (Acker 2006; Ng and Sears 2017; Ugarte and Rubery 2021; Zhu et al. 2022). However, it is difficult to achieve equity when the decision-making parties do not have adequate tools to facilitate equitable decisions over multivariate data.

Furthermore, employee motivation and its effect on superiors may not be based on objective variables of performance but instead on vital or current needs, or even on biased comparisons between coworkers (Bobadilla and Gilbert 2017; Litano and Major 2016). As such, those in charge of making salary decisions and the organizational staff face cognitive bias and variance on issues related to internal equity.

This study presents a common organizational problem and proposes a solution that employs data science and machine learning tools. It consists of a methodology and a tool co-designed and validated by data scientists and HR practitioners (Vassilopoulou et al. 2022) to help standardize the salary proposal for new talent, as well as the annual salary increments of current employees, by analyzing existing data and using a machine learning method as a salary predictor to deal with multivariate information and decrease the human cognitive and machine bias and, thereby decreasing the discrepancies associated with subjective variables.

The contributions of this study are as follows: it develops a predictor that mitigates human clinical prediction errors using statistical prediction methods as identified by Kahneman and Meehl (Kahneman 2013; Meehl 2013), it validates determinant variables used in salaries for hundreds of employees, and it presents evidence of the use and consequences of AI in HR practice demonstrating a successful real case. Consequently, the article contributes to the realization of the optimistic vision of the future, where AI improves the efficiency and fairness of HR management (Charlwood and Guenole 2022).

Background

To mitigate the risks posed by human predictive errors (Daniel, Sibony, and Sunstein 2021) and machine bias (Hutchinson and Mitchell 2019), this study is based on existing literature on pay equity and the main data science used or properly prepared as well as the problem statement explained in the previous section.

Salary Decision Systems

The concern of employers and employees on salary decision systems has been around for many years. This concern was exacerbated by pay disparities found in several salary studies relating to gender pay gap, which led to the formulation of equality laws and regulations in various countries. Most recent studies match pay equity with employee performance evaluation and focus on employee enhancement and productivity based on employee performance which improves their salaries (Aghdaie, Ansari, and Amini Filabadi 2020; Chikwariro, Bussin, and De Braine 2021; Loyarte-López et al. 2020; Reddy 2020). These studies do not contemplate gender issues in their cornerstone since their purpose is to analyze how employee performance can positively affect their salary and motivation and also what kind of extrinsic or intrinsic motivation impacts their performance. In the existing literature, there are articles that expressly study gender differences in salaries in certain sectors such as medicine (Kapoor et al. 2017; Mensah et al. 2020; Popovici et al. 2021; Wiler et al. 2021), surgery (Sanfey et al. 2017), services industry (Kronberg 2020), industry (Goraus, Tyrowicz, and van der Velde 2017), physician collective (Dan et al. 2021; Hayes, Noseworthy, and Farrugia 2020), higher education (Taylor et al. 2020), and banking sector (Tianyi, Jiang, and Yuan 2020). These kinds of studies attempt to promote equal changes for women and, after exhaustive analysis, propose structural and individual solutions to achieve equality not only in terms of salary but also in terms of promotion.

Few studies include automation-based assessments. Most of the studies are based on statistical studies and human resources practices. A recent article discomposes the gender wage gap using a LASSO estimator (Böheim and Stöllinger 2021). This estimator is valid to select among a large number of explanatory variables in wage regressions for a decomposition of the gender wage gap. After reviewing existing literature, we found that studies that validate machine-learning tools and consider real organizations and salary decision-making processes are scarce.

Existing studies provide different approaches to improving pay equity. Although there has been more activity recently in HR Management (HRM) through technological tools, this study contributes to the literature by providing a data science approach to developing a salary assessment methodology to validate salary determinants or factors. Moreover, the theories put forward by Meehl (2013) and Kahneman (2013) are a qualitative leap both in literature and organizational practice. As Meehl (2013) demonstrated in his analysis of clinical decision making, mechanical prediction achieved through decision rules that determine the valid criteria for decision making tends to be more accurate than the expert judgment of clinicians. Likewise, in his Nobel prize-winning research, Kahneman (year) demonstrated with his studies that human

beings are prone to big prediction errors that can be overcome by using algorithmic approaches.

Bias in HR Algorithms

Concern exists around the impact of AI in the field of HRM. Both positive and negative visions of the future are likely to coexist (Charlwood and Guenole 2022). Studies to prevent negative influences of AI in HR practices exist, such as Vassilopoulou et al. (2022). They examine more than 10,000 manuscripts on HRM, inequality, bias, diversity, discrimination, and algorithm keywords. Finally, after an exhaustive search, 60 papers focusing on AI bias in HR practices as the cornerstone theme were selected for this study. They conclude that there are five ways through which HR algorithms can influence inequalities in organizations: programmed for bias, proxies, algorithmic specification of fit, segregation for individuals, and technical design. To mitigate these biases, they also develop a bias proofing methodology for algorithmic hygiene for HR professionals to reinforce and consolidate HR practices.

According to positive vision, AI (Data Science and Machine Learning) can help create methods and tools that complement human reasoning and improve decision-making in various fields. The management field is in dire need of these technologies because decisions made by managers are mostly complex and multidimensional, affecting the efficiency and efficacy of the organization, as well as its work environment. Current data science methodologies (Martinez, Viles, and Olaizola 2021) can help managers select the appropriate criteria and implement good-performing machine-learning tools to improve internal equity and transparency (Viroonluecha and Kaewkiriya 2018).

AI has started transforming the world of work (Heath 2019; Sipahi and Artantaş 2022; Spencer 2017) and it is going to affect it. It can dramatically affect positively in terms of efficiency and fairness or can provoke unforeseen or negative consequences when it is finally implemented and used.

This study contributes to the literature in terms of exploring a method designed to mitigate conscious and unconscious biases (both human and machine biases) in the decision-making process and validation with actual results in a research technology organization. A technological tool (a salary predictor) co-designed by data scientists and HR Managers was developed. According to the contribution of practitioners, this study represents a successful real case of AI, where machine-learning techniques help managers make the most equitable and least biased salary decisions possible, based on real data and facts.

The predictor is used to negotiate salaries with new talent acquisitions and as a basis to decide salary increases.

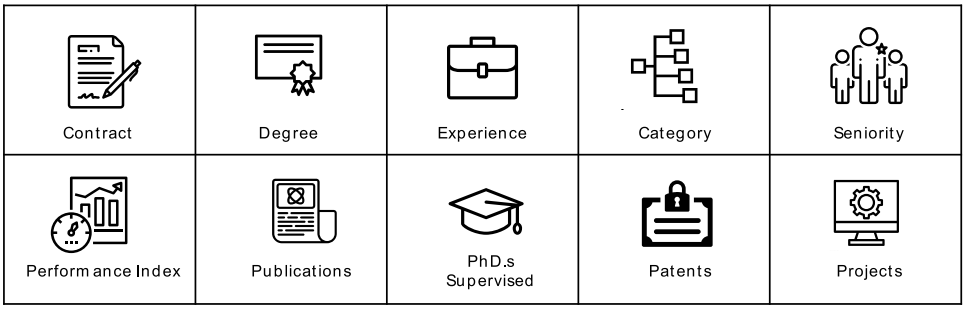

Figure 1. Salary determinant variables at the validating organization.

Validating Organization

Data validation is executed on a research technology organization located in the Basque Country of Spain. Its main business activity is R&D aimed at enhancing the innovative performance of industry and society. The organization is a nonprofit foundation with different research outputs, ranging from basic research to experimental prototype development (technology readiness levels 3–7).

Research Methodology

The exploration carried out in this study consists of a contextual analysis (Fantaw et al. 2020). In this case, the incidence of each variable mentioned in Figure 1 in the final result (salary) of each researcher is analyzed. This analysis makes the salary predictor much more precise than the classic job evaluation methodology because its talent is quoted.

The methodological ranking applied and the flow of steps are the follows:

- Data collection
- Validation method
- Salary predictor design requirements
- Prediction model: training process
- Salary policy assessment
- Results

Data Collection

The personnel of the organization are researchers, 40% of them hold doctoral degrees, working in a variety of technology domains. This research technology organization increased its employees by 75.43% in the last 5 years, including

Table 1. Employee turnover and increase during 5 years.

Date	Total employees	Departures	Staff increase
01/01/2017	114	86	75.43%
31/12/2021	200		

the departure of 86 employees (see Table 1). In this sense, the staff movement and salary reviews are very high and require a considerable amount of time.

The performance-measurement variables for researchers are based on objective criteria such as scientific publications, projects managed, patents achieved, and degrees (see Figure 1) (Loyarte-López et al. 2020, 2020). Consequently, the validation and examples developed in this study are based on this organization. However, this method is replicable in other types of organizations with different variables and criteria and HRM data-driven culture (Lin et al. 2022).

There are four researcher categories according to "seniority:" principal researcher, senior researcher, staff researcher, and junior researcher." Each category has its minimum requirements and promotion merits. These variables are included in Figure 1. In conclusion, salary determinant variables and the variables which influence the performance evaluation and the career development of each researcher have a full match and coherence as they are the same variables.

The data was collected in January 2021. At that moment the organization had 131 researchers: 5 principal researchers, 23 senior researchers, 46 staff researchers, and 56 junior researchers. Of these 131 researchers, 76 had assessment data available because their performance was evaluated in the previous year (these 76 researchers constituted the sample used as the training dataset. The data collected was enough for the research, given that all the researchers were distributed in four different categories with the same parameters. They are all very similar.

Data processing was carried out through the KNIME program. While most machine learning tools require programming skills, some tools such as KNIME (Berthold et al. 2006) allow users to visually prepare (ETL Extract, Load Transform), train, validate and plot machine learning models and prediction results. Therefore, the methods described in this paper were implemented on KNIME (see Figure 2).

Method

The proposed method is structured in two main phases (Figure 3). The first one consists of the assessment of data. Salary information is analyzed to assess that value and equity criteria established by the organization are reflected in data. There are several statistical and machine-learning tests that are used to validate whether the criteria of the organization are reflected in the data. Basic statistical

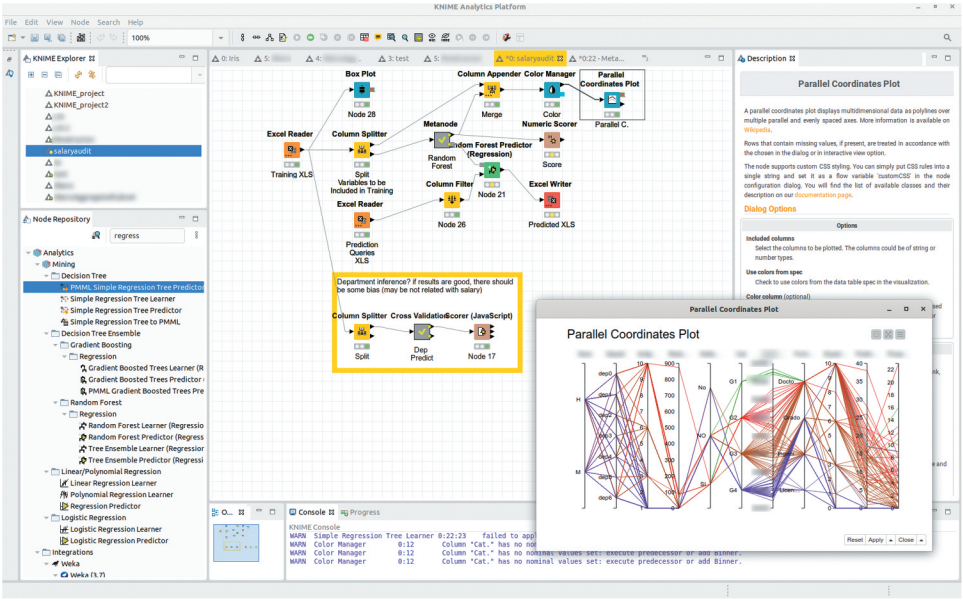

Figure 2. KNIME user interface.

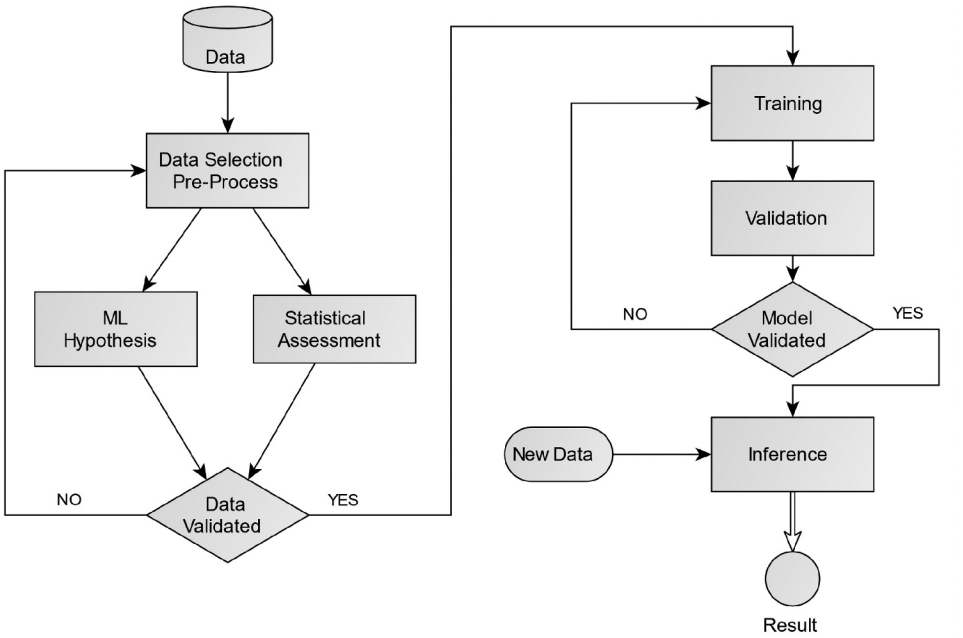

Figure 3. Validation method.

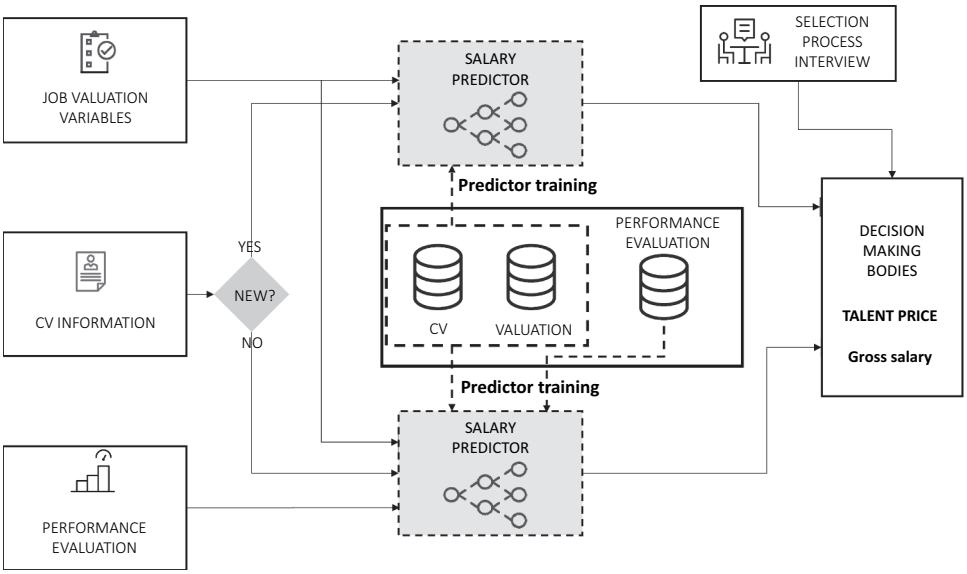

Figure 4. Employee salary decision framework.

measurements such as mean/variance and median or Student's-t test are hard to apply as multiple input variable values are different for targeted groups such as gender, nationality, or department. However, visual analytics techniques together with dimensionality-reduction techniques can help observe coherence in data and identify exceptions or anomalies as outliers. Moreover, machine-learning methods can be used to validate or refute hypotheses (e.g. gender bias hypothesis).

Once data quality and coherence (against bad policies and biases) are ensured by preprocessing and evaluating input data, we apply a method endowed by a machine-learning-based predictor for the process of hiring talent in any organization (Figure 4). Personnel suitable for the position are selected based on the variables used for performance evaluation, and the talent criteria used to verify these variables. The objective analysis is combined with subjective information obtained during the interview. At this point, subjective and negotiable variables are considered. At this point, a regressor is introduced to obtain a reference value free of any human bias that is used as the baseline for the final decision. This way, the machine-learning-based regressor acts as a decision support system.

Moreover, the same method can be used for salary assessment by using the predictor to identify the coherence inherent in the salary-related data and fix potential deviations.

Salary Predictor Design Requirements

The current plethora of prediction methods require clear design criteria and method that help the mitigation of human and machine bias. The most

suitable criteria must be selected for these employees (researchers). As the prediction target in our case is a numeric value (salary), we selected those oriented to regression tasks. Furthermore, as input data can include numerical and categorical data and the training dataset does not contain a big number of samples (around 130 samples), the selected methods must converge rapidly. In our case, the dataset is composed of 11 variables and k-fold 10 cross-validation is used to validate that the prediction model converges to an accurate bias-variance balance.

Regarding the bias/variance tradeoff (Belkin et al. 2019), in this case, low variance is a more relevant aspect as the target (salary) should not show high sensitivity to small fluctuations in input data.

The predictor should be co-designed and co-created by HR practitioners and data scientists to achieve effectiveness based on the two approaches and combine a successful combination of both types of knowledge with the aim of safeguarding ethical values regarding the importance of human dignity and justice (Raisch and Krakowski 2021; van den Broek, Sergeeva, and Huysman Vrije 2021). In this process, the assessment of the predictor is also very relevant to determine whether historical data contains any biases.

According to Vassilopoulou et al. (2022), bias proofing for algorithmic hygiene for HR professionals should be also done to ensure compliance with the laws and social justice requirements and to achieve a machine-bias-free predictor. Our predictor should comply with the AI Act of the European Parliament (European Parliament and the Council 2021).

The last requirement is that, to understand the influence of each factor and to assess the fairness of the model, the method used should be interpretable. This is especially relevant to provide valuable information about how each individual case should improve and check the behavior of the model. We could verify whether the variables identified by the model as the most relevant are the ones that the organization wants to foster.

Prediction Model

Different regression models were tested, including linear regression, ridge regression, Lasso regression, SVM, gradient boosting, random forest, neural networks, Bayesian ridge, Ada boost, and KNN. In the case of the recruitment dataset, random forest (RF) (Breiman, 2001) is the only model that has consistently provided a mean absolute percentage error below 4% (Table 3) after performing random K-fold 10 cross-validation experiments, while annual salary review dataset is better predicted using gradient boosting regressor (GBR) (Friedman 2001).

All the requirements established in the previous section and the good performance scores led us to select RF as the regression method for recruitment and GBR for salary review. Both methods offer relatively good

explainability (Figure 5 shows the variable importance according to predictors), tend to keep low variance and can compute different input data types (numeric and categorical). However, it is important to heed that a similar systematic comparative regression method benchmark should be applied to any new dataset.

Training Process

We used the salary database of the organization to build two predictors: one to calculate the employee salary in the recruitment process and the other to calculate annual salary increases, considering performance evaluations from recent years (three periods, for instance). We used the variables included in the performance measurement system designed and developed by the research technology organization.

The accuracy results of the two models (annual salary review where the performance index is calculated based on internal KPIs and recruitment dataset, where the performance index cannot be obtained and therefore is removed from the training) are shown in Table 2, and training performance statistical data is presented in Table 3.

The training dataset can be improved by increasing the internal coherence of data. In this sense, outliers and samples that are inconsistent with the internal policies must be removed. This task was performed during the

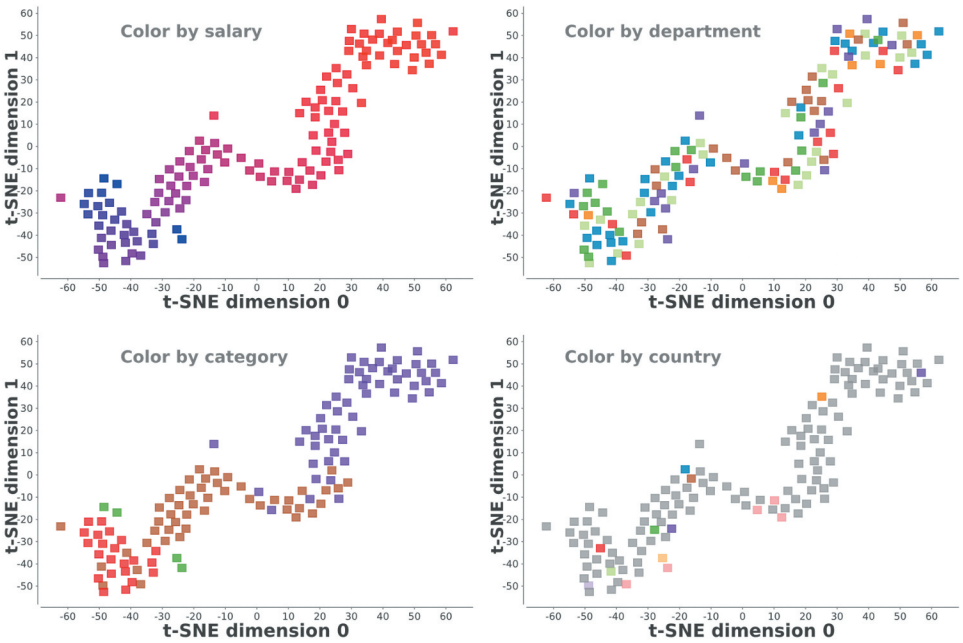

Figure 5. t-SNE dimensionality reduction.

Table 2. Training and assessment variables.

Salary Policy Training			Salary Policy Assessment
Contract	Education (PhD., Master, Degree, etc.)	Experience	Country of origin
Category	Publications	Patents	Reduction of working hours
Seniority	PhD supervised	Projects	Department
Performance Index (Scores)	Management responsibilities		Gender

Table 3. Training Performance.

Dataset	Samples	R2	Mean absolute percentage error	Percentage error variance
Recruitment	138	0.91	0.0375	0.003
Annual Salary Review	76	0.9	0.0496	0.004

assessment process. Moreover, feature space can be enriched by creating synthetic data according to the rules and criteria of the organization.

Salary Policy Assessment

The goal of the salary assessment process is to ensure that salary decisions are taken based on general policies that promote the goals of the organization (fairness, equity, performance, etc.) To mitigate human bias, we propose the use of machine-learning methods that extend the more classical statistical methods (A/B tests, Student T test, null hypothesis, etc). Our proposed approach includes three main strategies:

- Visual analysis by dimensionality-reduction techniques
- Explainability analysis of the prediction model
- Hypothesis testing by changing the input variables of the prediction model

Visual Analysis by Dimensionality Reduction

Visual cluster analysis can show how data are spread in feature space. We experimented using t-SNE method (Van Der Maaten and Hinton 2008) on our dataset and found a continuous path where categories and salaries evolve. Other features such as sex, origin, and department were randomly distributed. Figure 4 shows some examples of t-SNE representations where different criteria are shown as color codes to verify if clusters or patterns apply.

As observed in Figure 5, while salary and category follow a clear pattern where even clusters can be visually distinguished, other aspects such as department or country of origin are randomly distributed. In other words, each cluster is represented by one color, and therefore, it can be visualized how salary and category follow a color order and departments and country are fuzzy.

Explainability

Even if models such as random forest can provide variable importance inherent to the model used, other explainable methods such as SHAP provide a deeper insight regarding the way these variables influence prediction. Figure 6 shows the SHAP values where *Projects* and *Publications* appear as the main factors for salary reviews. Even if the impact of *Category* is also relevant, this variable has a strong dependence on *Education* and *Performance Scores*. In the case of the recruitment dataset, *PhD* is a highly discriminant variable, and then *Experience*, *Publications*, and *Projects* show a similar impact. As with the salary reviews dataset, *Category* reflects a direct strong effect in salary but depends on the rest of the variables. Aspects such as *Country of Origin*, *Gender* or *Department* are below the threshold. Performance index scores have less relevance because they have been conditioned by the variables that already show a big influence in the final prediction.

Hypothesis Testing

Finally, we propose the use of hypothesis testing as the third assessment method. In this case, the salary is used as input data and variables such as *gender*, *department*, or *country of origin* (which are supposed to be unrelated to salary-related decisions) are transformed into the target of the prediction method. If the accuracy of the predictor is not clearly better than the random baseline, it can be assumed that this feature is not relevant to salary-related decisions.

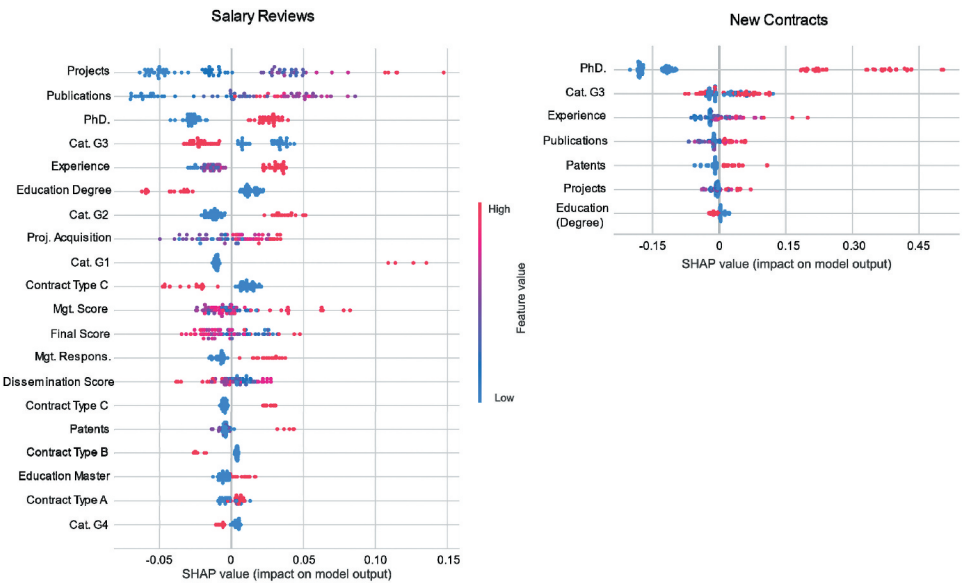

Figure 6. SHAP variable importance for random forest (New recruitments) and gradient boosting regressor (salary review). Variables with no significant relevance have been omitted.

In both the recruitment and salary review datasets, gender class is strongly unbalanced toward men with the consequent risk of bias. The behavior of tested classifiers in both cases tends to lean toward the majority class. The application of dataset balancing methods (upscaling, downscaling, SMOTE, etc.) can mitigate this effect. Upscaling was used in this case. As predictors are not able to predict women in the datasets (precision is below 0.5 in the salary review dataset and 0.67 in the recruitment dataset while a random predictor should have 0.5 of baseline accuracy). Similarly, a department predictor has given an accuracy of 0.227 (recruitment) and 0.33 (salary review) while the random baseline would be 0.143.

If the same approach is applied with a variable that has been identified as relevant (e.g., category) accuracy rises to 0.882 (salary review dataset) and 0.93 (recruitment dataset) while the random baseline would be 0.25 (4 categories), showing that all these results are consistent with the variable relevance information.

Results

The main result is that the salary predictor worked. The three salary assessment strategies show that the predictor is sensitive to the salary determinant variables indicated in Figure 1. If one mentioned variable changes, it affects salary. HR practitioners of the organization carry out double checks to verify that the results acquired by the predictor are correct (guarantee internal equity).

Discussion

The salary predictor developed through data science explained in this paper was used as a tool that provides a salary reference in 130 employee cases, 70 acquisitions in 2021, and other 200 cases of salary increases in 2022. Even if the dataset size might seem quite limited, the created feature space satisfies the needs of the employed methods for prediction and assessment in terms of predictability, consistency, and explainability. In this section, we structured the reporting of the empirical results from a statistical, theoretical, and practical perspective.

Statistically, the following findings have been obtained during the process:

- Consistency in 70 talent acquisition processes: We found that salary estimates by the tool are appropriate not only to offer a salary and start a negotiation but also to know the rank where the organization can move in each negotiation. The data provided by the predictor is scrutinized by managers to assess whether the salary information is consistent with that of similar profiles.

- Consistency in salary review/assessment in 130 cases: We analyzed all cases to visualize salary and merits. This analysis has made it possible to carry out an individualized study of all the cases and make decisions to fix those cases in which a deviation was identified by the assessment process (deviations are identified as outliers in the dimensionality reduction visual representation and tend to have the highest errors when compared with the random forest regressor predictions.

Theoretically, this research contributes to the following:

- The predictor can mitigate conscious and unconscious bias as it is based on objective data. Consequently, the resulting salary is more acceptable at the first instance to the employee than it is when determinant variables are subjective.
- This methodology is valid not only to mitigate the gender gap but also to mitigate other diversity gap factors (including internal variables such as different departments).
- As Charlwood and Guenole (2002) conclude in their study, misconceptions about AI also exist. There are typical objections like "HR data is bad data,""AI reproduces discriminatory behaviors produced by human biases," or "AI are only functionally black boxes" that they are not real in the case explained in this article. HR data is good data because it is objective-based data, not based on opinions or subjective judgments, and in this case, an assessment has been implemented not to reproduce any previous mistake (every outlier was exhaustively studied).
- This is a real AI case, not a hypothetical scenario.

Finally, practically, the main lessons learned are the following:

- It is very important to develop key determinant factors or variables for salaries in an organization, and they need to be transparent and acceptable for employees. Employees can compare with each other and therefore, organizations must focus their comparison in terms of key determinants variables. The predictor works properly in terms of consistency between factors "results per employee" and "salary amount."
- A data-driven HRM culture is crucial for the organization to start working on AI in HR field and to achieve acceptance by employees.
- Employees are more than a number of achievements and indicators, as it could happen that some intangible assets or variables are ignored by the predictor. Consequently, the predictor should be a tool to help in decision making rather than making decisions by itself. The predictor should be reviewed every year to evaluate whether it is working properly and to improve it (preventive maintenance).

- Predictor designers and creation teams are crucial to achieving a successful tool. Their knowledge, collaboration, and good understanding as well as their commitment to developing a fair predictor are very important.

There are some limitations in the research validation of this study:

- It has been validated through casuistry by employees of an organization with previous literature in the objective standardization of the professional career and performance of its researchers. Its generalization to other organizations or companies might require adaptations in the variable selection and assessment process.
- This study could offer a more exhaustive state-of-the-art prediction model, but it has been focused on practical and replicable work. The aim of this article is to encourage and help other organizations to develop salary predictors to comply not only with current laws but also with the commitment to internal equity. Moreover, it contributes a new solution to frequently studied salary audit gaps and bias to the scientific community.

We consider that our methodology can be successfully extended to other organizations. The presented method can lead organizations to more objective decision making and higher accomplishments of established salary policies. This method might be especially useful when efforts and merits are difficult to measure, as is the case of R&D organizations and in medium-large organizations when salary decision-makers cannot know the performance of each employee.

For future work, we intend to review salary determinants to include other specific items to improve the model and test the acceptance of the model in other organizations. AI is a reality and therefore, thinking of how AI could improve our work is the first step toward working on emerging problems where AI could bring different skills, such as scientists and practitioners, to work together for mutual benefit.

Conclusion

This study demonstrates how to develop a method based on artificial intelligence for deciding the internal value of talent in an organization and for evaluating the salary criteria. The presented method helps to minimize the subjectivity of decision-making bodies and ensures consistency in internal equity throughout the organization and over time, improves objectiveness and fairness of organizations in talent management.

As Thomas Aquinas stated, "There will be the same equality between persons and between things in such a way that, as things are related to one

another, so are persons. If they are not equal they will not have equal shares, and from this source quarrels and complaints will arise, when either persons who are equal do not receive equal shares in distribution, or persons who are not equal do receive equal shares." (Thomas 1993). This study contributes to making decisions that determine the salary of employees based on their merits and abilities, as well as on the organizational requirements.

To sum up, the method and therefore the predictor must be faithful to the variables and politics to which it responds, meanwhile, decision-making bodies should respect the results of the predictor that responds to the designed system. When technology and humans follow the frameworks and systems designed and implemented, subjectivity is mitigated and effectiveness and productivity increase.

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Disclosure Statement

No potential conflict of interest was reported by the author(s).

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Data Availability Statement

The data that support the findings of this study are in the validating organization.

References

AckerAcker, J. 2006. Inequality regimes. *Gender & Society* 20 (4):441–64. doi:10.1177/0891243206289499.

Aghdaie, S. F. A., A. Ansari, and M. Amini Filabadi. 2020. Comparing the effects of brand equity, job security and salary and wages on the efficiency of human resources from the perspective of the staff. International Journal Procurement Management 13 (3):397–418.

Belkin, M., D. Hsu, S. Ma, and S. Mandal. 2019. Reconciling modern machine-learning practice and the classical bias–variance trade-off. *Proceedings of the National Academy of Sciences of the United States of America* 116 (32):15849–54. doi:10.1073/pnas.1903070116.

Berthold, M. R., N. Cebron, F. Dill, G. Di Fatta, T. R. Gabriel, F. Georg, T. Meinl, P. Ohl, C. Sieb, and B. Wiswedel. 2006. KNIME: The Konstanz information miner. *4th International*

Industrial Simulation Conference 2006, ISC 2006, 58–61. EUROSIS. doi:10.1145/1656274.1656280.

Bobadilla, N., and P. Gilbert. 2017. Managing scientific and technical experts in R&D: Beyond Tensions, conflicting logics and orders of worth. *R&D Management* 47 (2):223–35. doi:10.1111/radm.12189.

Böheim, R., and P. Stöllinger. 2021. Decomposition of the gender wage gap using the LASSO estimator. *Applied Economics Letters* 28 (10):817–28. doi:10.1080/13504851.2020.1782332.

Charlwood, A., and N. Guenole. 2022. Can HR adapt to the paradoxes of artificial intelligence? *Human Resource Management Journal* January doi:10.1111/1748-8583.12433.

Chikwariro, S., M. Bussin, and R. De Braine. 2021. Reframing performance management praxis at the Harare city council. *SA Journal of Human Resource Management* 19 (January). doi:10.4102/sajhrm.v19i0.1438.

Daniel, K., O. Sibony, and C. R. Sunstein. 2021. *Noise: A flaw in human judgment*. London: Little, Brown Spark.

Dan, Z., M. Liao, P. Wang, and H.-C. Chiu. 2021. Development and validation of an instrument in job evaluation factors of physicians in public hospitals in Beijing, China. Edited by Ritesh G. Menezes. *Plos One* 16 (1) : e0244584. doi:10.1371/journal.pone.0244584.

European Commission. 2014. *Commission recommendation of 7 March 2014 on strengthening the principle of equal pay between men and women through transparency*. Brussels.

European commission, directorate-general for research and innovation. 2021. *Horizon Europe Guidance on Gender Equality Plans*. doi:10.2777/876509.

European Parliament and the Council. 2021. Laying down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts. https://eur-lex.europa.eu/legal-content/EN/TXT/DOC/?uri=CELEX:52021PC0206&from=ES.

Fantaw, A., S. K. Gupta, P. Reznik Nadia, E. Sipahi, and S. D. F. Teston. 2020. Analysis of the effect of compensation on twitter based on job satisfaction on sustainable development of employees using data mining methods. *Talent Development & Excellence* 12 (3):35.

Friedman, J. H. 2001. Greedy function approximation: A gradient boosting machine. *Annals of Statistics* 29:5. doi:10.1214/aos/1013203451.

Goraus, K., J. Tyrowicz, and L. van der Velde. 2017. Which gender wage gap estimates to trust? A comparative analysis. *Review of Income and Wealth* 63 (1):118–46. doi:10.1111/roiw.12209.

Hayes, S. N., J. H. Noseworthy, and G. Farrugia. 2020. A structured compensation plan results in equitable physician compensation. *Mayo Clinic Proceedings* 95 (1):35–43. doi:10.1016/j.mayocp.2019.09.022.

Heath, D. R. 2019. Prediction machines: The simple economics of artificial intelligence. *Journal of Information Technology Case and Application Research* 21 (3–4):163–66. doi:10.1080/15228053.2019.1673511.

Hutchinson, B., and M. Mitchell. 2019. 50 years of test (Un)Fairness. *Proceedings of the Conference on Fairness, Accountability, and Transparency*, 49–58. New York, NY, USA: ACM. 10.1145/3287560.3287600.

Kahneman, D. 2013. Thinking, fast and slow https://en.wikipedia.org/wiki/Thinking,_Fast_and_Slow.

Kapoor, N., D. M. Blumenthal, S. E. Smith, I. K. Ip, and R. Khorasani. 2017. Sex differences in radiologist salary in U.S. public medical schools. *American Journal of Roentgenology* 209 (5):953–58. doi:10.2214/AJR.17.18256.

Kronberg, A.-K. 2020. Workplace gender pay gaps: Does gender matter less the longer employees stay? *Work and Occupations* 47 (1):3–43. doi:10.1177/0730888419868748.

Lin, S., E. Sipahi Döngül, S. Vural Uygun, M. Başaran Öztürk, D. Tran Ngoc Huy, and P. Van Tuan. 2022. Exploring the relationship between abusive management, self-efficacy and organizational performance in the context of human–machine interaction technology and

artificial intelligence with the effect of ergonomics. *Sustainability* 14 (4):1949. doi:10.3390/su14041949.

Litano, M. L., and D. A. Major. 2016. Facilitating a whole-life approach to career development. *Journal of Career Development* 43 (1):52–65. doi:10.1177/0894845315569303.

Loyarte-López, E., I. García-Olaizola, J. Posada, I. Azúa, and J. Flórez. 2020. Sustainable career development for R&D professionals: Applying a career development system in Basque country. *International Journal of Innovation Studies* 4 (2):40–50. doi:10.1016/j.ijis.2020.03.002.

Loyarte-López, E., I. García-Olaizola, J. Posada, I. Azúa, and J. Flórez-Esnal. 2020. Enhancing researchers' performance by building commitment to organizational results. *Research-Technology Management* 63 (2):46–54. doi:10.1080/08956308.2020.1707010.

Maaten, L. V. D., and G. Hinton. 2008. Visualizing data using T-SNE. *Journal of Machine Learning Research* 9. http://jmlr.org/papers/v9/vandermaaten08a.html.

Martinez, I., E. Viles, and I. G. Olaizola. 2021. Data science methodologies: Current challenges and future approaches. *Big Data Research* 24 (May):100183. doi:10.1016/j.bdr.2020.100183.

Meehl, P. E. 2013. *Clinical versus statistical prediction: A theoretical analysis and a review of the evidence*. Echo Point Books.

Mensah, M., W. Beeler, L. Rotenstein, R. Jagsi, J. Spetz, E. Linos, and C. Mangurian. 2020. Sex differences in salaries of department chairs at public medical schools. *JAMA internal medicine* 180 (5):789. doi:10.1001/jamainternmed.2019.7540.

Ng, E. S., and G. J. Sears. 2017. The glass ceiling in context: The influence of CEO gender, recruitment practices and firm internationalisation on the representation of women in management. *Human Resource Management Journal* 27 (1):133–51. doi:10.1111/1748-8583.12135.

Popovici, I., M. J. Carvajal, P. Peeples, and S. E. Rabionet. 2021. Disparities in the wage-and-salary earnings, determinants, and distribution of health economics, outcomes research, and market access professionals: An exploratory study. *PharmacoEconomics - Open* 5(2):319–29. January doi: 10.1007/s41669-020-00247-2.

Raisch, S., and S. Krakowski. 2021. Artificial intelligence and management: The automation–augmentation paradox. *Academy of Management Review* 46 (1):192–210. doi:10.5465/amr.2018.0072.

Reddy, V. S. 2020. Impact of compensation on employee performance. *IOSR Journal of Humanities and Social Science* 25 (9):17–22. www.iosrjournals.org.

Sanfey, H., M. Crandall, E. Shaughnessy, S. L. Stein, A. Cochran, S. Parangi, and C. Laronga. 2017. Strategies for identifying and closing the gender salary gap in surgery. *Journal of the American College of Surgeons* 225 (2):333–38. doi:10.1016/j.jamcollsurg.2017.03.018.

Sipahi, E., and E. Artantaş. 2022. Artificial intelligence in HRM. 1–18. doi:10.4018/978-1-7998-8497-2.ch001.

Somayya, M., R. M. Holmukhe, and D. Kumar Jaiswal. 2019. The future digital work force: Robotic process automation (RPA). *Journal of Information Systems and Technology Management* 16 (January):1–17. doi:10.4301/S1807-1775201916001.

Sowa, K., and A. Przegalinska. 2020. Digital coworker: Human-AI collaboration in work environment, on the example of virtual assistants for management professions. *Collaborative innovation networks conference of Digital Transformation of Collaboration*, 179–201. Cham: Springer. doi:10.1007/978-3-030-48993-9_13.

Spencer, D. 2017. Work in and beyond the second machine age: The politics of production and digital technologies. *Work, Employment and Society* 31 (1):142–52. doi:10.1177/0950017016645716.

Taylor, L. L., J. N. Lahey, M. I. Beck, and J. E. Froyd. 2020. How to do a salary equity study: With an Illustrative example from higher education. *Public personnel management* 49 (1):57–82. doi:10.1177/0091026019845119.

Thomas, A. O. P. Notre Dame Trans: C. I. Litzinger. 1993. *Commentary on Aristotle's Nicomachean Ethics*. Dumb Ox Books https://www.amazon.com/Commentary-Aristotles-Nicomachean-Ethics-Aristotelian/dp/1883357519.

Tianyi, M., M. Jiang, and X. Yuan. 2020. Cash salary, inside equity, or inside debt?—The determinants and optimal value of compensation structure in a long-term incentive model of banks. *Sustainability* 12 (2):666. doi:10.3390/su12020666.

Ugarte, S. M., and J. Rubery. 2021. Gender pay equity: Exploring The impact of formal, consistent and transparent human resource management practices and information. *Human Resource Management Journal* 31 (1):242–58. doi:10.1111/1748-8583.12296.

van den Broek, E., A. Sergeeva, and M. Huysman Vrije. 2021. When the machine meets the expert: An ethnography of developing AI for hiring. *MIS Quarterly* 45 (3):1557–80. doi:10.25300/MISQ/2021/16559.

Vassilopoulou, J., O. Kyriakidou, M. F. Özbilgin, and D. Groutsis. 2022. Scientism as illusio in HR algorithms: Towards a framework for algorithmic hygiene for bias proofing. *Human Resource Management Journal* January doi:10.1111/1748-8583.12430.

Viroonluecha, P., and T. Kaewkiriya. 2018. Salary predictor system for Thailand labour workforce using deep learning. *2018 18th International Symposium on Communications and Information Technologies (ISCIT)*, 473–78. Bangkok, Thailand: IEEE. 10.1109/ISCIT.2018.8587998.

Wiler, J. L., S. K. Wendel, K. Rounds, B. McGowan, and J. Baird. 2021. Salary disparities based on gender in academic emergency medicine leadership. *Academic Emergency Medicine* 29 (3):286–93. December doi: 10.1111/acem.14404.

Zhu, X., F. Lee Cooke, L. Chen, and C. Sun. 2022. How inclusive is workplace gender equality research in the Chinese context? Taking Stock and looking ahead. *The International Journal of Human Resource Management* 33 (1):99–141. doi:10.1080/09585192.2021.1988680.

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Sustainable career development for R&D professionals: Applying a career development system in Basque country

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ABSTRACT

The goal of this study is to measure the effectiveness of a career development system implemented at a research and technology organization at satisfying the context requirements of a decree issued by the Basque Country government. Through in-depth surveying of 80 R&D professionals over the five years, the authors aimed to determine whether a career development system, when it is linked to context requirements and researchers' contributions, could offer researchers feedback about their career aims and increase their job satisfaction. During the five years of the study, the researchers' capacity to meet career requirements improved by 20%, and job satisfaction, although it declined at first, increased substantially in the last two years, reaching a historic high for the employee satisfaction survey.

1. Introduction

There is a long tradition of analysis of the relationship between job satisfaction and job performance but in the field of organizational psychology, the topic is currently receiving much interest. Current studies are usually conducted from the perspective of workplace attitudes and productivity (Judge, Thoresen, Bono, & Patton, 2001) or researchers' willingness factors to engage in R&D activities (Abdulla, Djebarni, & Mellahi, 2011; Olaya et al., 2017).

Research and technology organizations (RTO), the major focus of this study, are centres of knowledge generation and dissemination that provide policies, methods, and resources for R&D activities. Most RTOs in Spain are located in the Basque Country. More than 3000 researchers are RTOs' employees in Basque Country. In consequence, the management of their professional career is critical and it affects their job satisfaction and performance.

Although the literature contains several qualitative and quantitative studies and models, these need to be tested in new organizations in order to validate the models. This validation would contribute significantly to the literature and assist practitioners. In consequence, this study contributes to the literature providing an implemented and verified career development system that accounts for the concerns of context requirements (results) and researchers (satisfaction) and responding to employee incentives and long-term plans (career development).

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Basque Country has recently undergone an important technology transformation, and its innovation system is now focused on new technologies and on trying to make a place for itself among the most advanced economies; its new approach is based on knowledge management, interaction, and transfer within Basque society and with other European regions (Basque Government, 2014). Decree 109 was enacted in 2015 to regulate the Basque Science, Technology, and Innovation Network, and this decree reorganized the network, defining the position of each RTO in terms of its research specialization, achievements, status within the R&D value chain, and the results it could be expected to produce. Consequently, each RTO had to align its corporate strategy with the government's guidelines and expectations, the crucial element of which was employee career development (Decree 109/2015 June 23, 2015).

More specifically, in this Decree, RTO key performance indicators and professional career goals were redefined to improve RTO efficiency. One of the mandatory programs for the Decrees' 2020 milestone is Professional Careers (Decree 109/2015 Annex II), which defined key requirements for a variety of research and directorial/management positions within RTOs (Tables 1 and 2).

The cornerstone of these RTOs is employees as they have the vital knowledge for the R&D which is a key strategic value for these organizations (Bremser & Barsky, 2004). Currently, managers and employers understand they cannot inspire good performances from their employees in an environment where both personal career management and organizational career management practices are absent. The development of new methods is necessary, which calls for a fundamental change of approach in this domain (Kaya & Ceylan, 2014).

Consequently, the primary challenge for this study was to develop an adequate and reliable career development system for the key performance indicators (determined by the requirements in Tables 1 and 2) that maintains or improves employee job satisfaction. Researchers' acceptance was needed since an RTO's performance depends on the performance of its researchers as well as their knowledge and motivation. Therefore, investments in human resources development and high-commitment strategies that influence employee commitment and motivation are necessary (Lee & Bruvold, 2003).

According to this motivation, this study makes the following research questions:

Research question 1: Does a new culture of organizational management based on a professional career development system within a holistic framework improve compliance with the Decree requirements?

Research question 2: Do human resources practices affect the job satisfaction of the R&D personnel?

This paper is divided into six sections. In the first two sections, a theory of career development and employee job satisfaction is developed, and hypotheses are presented. This theory and these hypotheses allow for the identification of variables that support the paper's analysis and implemented framework. Then, sections three through six present the study's methodology, findings, discussion, and conclusions.

Table 1
Requirements for direction/management careers: Decree 109/2015.

Levels	Description	Requirements	Associated positions
1	• Leads, plans and manages the global strategies and objectives of the Centre. • Provides a global vision of the organization.	• Doctorate degree. • Proven experience in the management of centres and large teams for 10 years. • Mastery of spoken and written English.	• Director-General • Scientific-Technological Director
2A	• Directs, plans and manages the strategy and objectives of a research area of the Centre, which may include several technological lines. • Ensures and contributes to the Centre's scientific and technological excellence. • Promotes and seeks new opportunities for growth and opening to new sectors and activities. • Participates in the governing bodies of the Centre.	• Doctorate degree. • High command of the variables of the market sector and proven track record for 5 years. • Mastery of spoken and written English.	• Area Director
2B	• Directs, plans and manages the strategy and objectives of a functional support area of the Centre. • Ensures and promotes excellence in management. • Participates in the governing bodies of the Centre.	• Master's degree or equivalent • Participates in the governing bodies of the Centre • Mastery of the variables of the market sector and proven track for five years in the process that leads. • Mastery of spoken and written English.	• Management • International Relations Director • Institutional Relations Director • Staff Area Director
3	• Leads a stable research staff or professionals while coordinating a portfolio of projects or services for the development of a research line, knowledge area or technological service. • Prepares, proposes and executes the objectives and plans for the management of the line or unit in their sphere of responsibility	• Doctorate degree • Proven track record in leadership of research teams for 5 years. • Mastery of spoken and written English	• Head of Technology Lines
4	• Transfers the vision to the operational management of the activities, people and economic and material resources of their unit/area. • Administration and/or technical support staff is included here.	• University or college degree • Proven trajectory in activities in the process for 2 years. • Mastery of spoken and written English.	• Staff Area

Table 2
Requirements for researchers: Decree 109/2015.

Levels	Description	Requirements
Main Researcher (G1)	• Acts as a reference, drives, leads, and manages the process of recruitment and development of proposals, detecting and interpreting customer needs and developing technical offers. • Searches, establishes and maintains a network of organizations or allied entities, employees and contracts: centres, universities, companies …	• Doctorate degree. • Professional experience: more than 10 years in research. • 10 indexed publications, articles and papers in the scientific environment and doctoral thesis supervision. • Languages: mastery of spoken and written English. • Projects: leadership of 2 international consortium projects with teams from more than 2 countries as well as management of autonomous parts (tasks, packages or subprojects) of 5 projects in national/international consortia • Participation in at least 1 patent; participation in the development of transferable technologies through international patents and license agreements will be valued.
Senior Researcher (G2)	• Participates in the process of attracting and preparing offers, detecting and interpreting customer needs and preparing technical offers. • Searches, establishes and maintains a network of organizations or allied entities, collaborators and contacts: centres, universities, companies …	• Doctorate degree. • Professional experience: more than 4–5 years in research. • 6 indexed publications. • Languages: Mastery of spoken and written English (at the level of work in international teams and writing) • Projects: management of autonomous parts (tasks, packages, subprojects) of 3 projects in national or international consortia and 5 projects/direct contracts with companies. • The participation in patents and in the development of transferable technologies will be valued
Junior Researcher (G3-G4)	• Prepares offers of projects of low and occasionally medium complexity • Relates to and contacts the network of organizations or allied entities, collaborators and contracts: centres, universities, companies …	• Doctorate degree, bachelor's degree or engineering. • G3: minimum of 2 indexed publications • Languages: Intermediate spoken and written English. • Knowledge of other languages will be valued

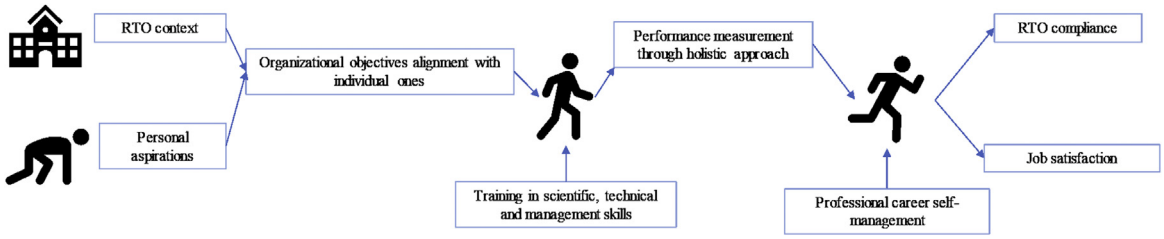

Fig. 1. Implemented framework.

2. Theory and hypotheses

Fig. 1 illustrates the implemented framework (big-picture conceptual model). As seen in the figure, at the beginning of a labor relationship, researchers have their own aspirations, and the RTO has its own objectives. The first unifying key for this relationship is the alignment of the RTO's objectives and key performance indicators with those of the individual so that the RTO's indicators and goals downscale to become the researchers. Researchers require training to comprehend the philosophy underlying this model and to make them aware of their own goals and the trajectory of their careers in the context of a particular RTO. Therefore, the methodology is integrated into a holistic framework, in which all human management processes are related within the people capability maturity model. With this framework in place, researchers contribute to fulfilling the RTO's objectives, and since they are responsible for their professional careers, they feel satisfied at work. As a result, on the one hand, RTO objectives are linked to context requirements, and on the other hand, researchers are satisfied with their research lines, projects, and the challenges they face. Researchers can monitor their professional career requirements using the application of informatics. Subsequently, they can visualize in real-time the requirements they have achieved and which ones they need to promote to the next category.

According to the study's conceptual framework, two key aspects will be reviewed: career development and employee job satisfaction. These two aspects guided the selection of an adequate organizational approach (new career development) that focuses on the satisfaction of the main protagonist (researchers).

2.1. R&D professional career development

The development of human resources is associated with organizational success. It is crucial to integrate employees into an organization and contemporaneously facilitate organizational dynamics, such as motivation, organizational commitment, and employee job satisfaction (Hobfoll, Halbesleben, Neveu, & Westman, 2018; Spurk, Hirschi, & Dries, 2018). Research on vocational psychology has confirmed that an individual progress along different lines at different stages of their careers and that at any given stage, these individuals have unique career concerns, developmental tasks, personal challenges, and psychological needs (Litano & Major, 2016). The greater the match or similarity between an individual's career goals and plans and the organization's plans for the employee, the more positive the outcomes of motivation and the greater the level of job satisfaction for the employee (Granrose, 1997).

A career development system is a key component of the activities of both individuals and organizations (Kaya & Ceylan, 2014), and these programs are usually explored as an isolated activity in organizations. In addition, career development has been primarily concerned with accumulating job competencies and gaining experience in a specific job (Akkermans, Brenninkmeijer, Huibers, & Blonk, 2013). In recent decades, however, more dynamic careers have become more common, with employees developing through horizontal shifts between multiple organizations (Arnold & Cohen, 2008). To obtain and retain a job in this changing labor market, individuals increasingly require career competencies to help them manage their careers (Van Der Heijde and Van Der Heijden, 2006).

Career development entails many different concerns, such as developing abilities, preserving current skills, and preparing for the future after promotion (Kaya & Ceylan, 2014). Companies invest in career development programs for several reasons: to enhance employee performance, increase managerial performance, teach corporate culture to salespeople, strengthen principal values, help salespeople with career improvement, and offer extra benefits to employees (Ko, 2012). Employees, especially young people, want to develop and be in control of their careers, and career development programs enable all workers to advance in an organization from the start of their careers. Such programs also help determine career paths and remove obstacles to career progress. Furthermore, such programs accelerate workflow in the organization by providing training for personnel whose career paths have been more stable and who are now experiencing increased mobility.

Some of the organizational career development practices addressed in the literature are job enrichment, career progression ladders, employee workshops, and job rotation. Some organizations recognize high-performing employees and provide them with a promising environment to take risks and achieve improved career resilience. The people capability maturity model (Fig. 2) is a roadmap for implementing practices that continuously improve the capability of an organization's workforce.

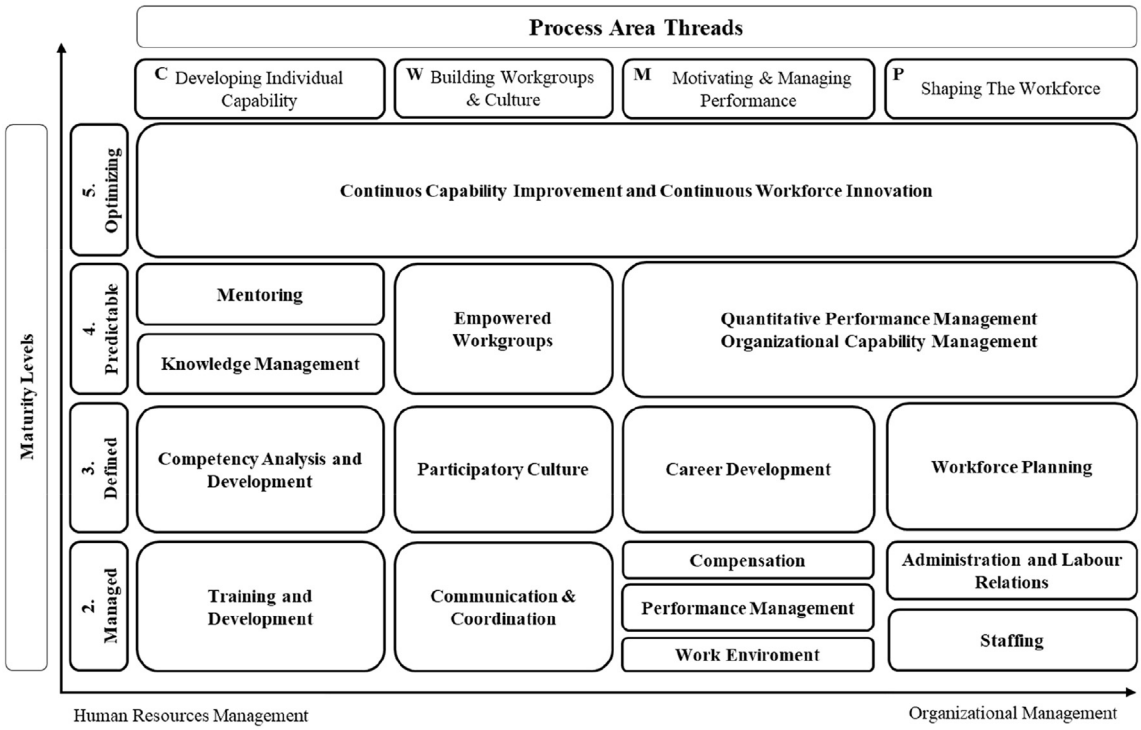

Fig. 2. People capability maturity model.

The above roadmap was published by Carnegie Melon University in 1995 (Curtis, Hefley, & Miller, 2002) as a foundation for a model of best practices for managing and developing an organization's workforce. Its primary objective is to improve the capability of the workforce. This study is focused on the design and implementation of career development processes, but this cannot be adequately introduced in the organization if it is not connected and coherently conducted with the rest of the processes such as training, performance measurement, or competency analysis and compensation. While the organization implements the career development system in parallel, the other processes need to be elaborated upon. The people capability maturity model offers the required guidelines to achieve this coherence among the processes, and in this study the focus is the career development process.

2.2. Employees' job satisfaction

General job satisfaction, the overall attitude of liking or disliking a job, is a universal and essential part of career development. One of the assumptions that employees have about their careers is that there ought to be a match between their aspirations and the organization's career system (Malhotra, Smets, & Morris, 2016). Some organizations may not seek to make such a match, and dissatisfaction and withdrawal may result (Cartwright, 2005).

This topic has been studied in different locations using a variety of perspectives, including motivation (Olaya Escobar et al., 2017), job performance (Judge et al., 2001), job impact (Taylor, 2014), demographic and environmental factors (Abdulla et al., 2011), and private or public administrations (Demircioglu, 2018).

There are nine facets to job satisfaction: pay, promotion, benefits, contingent rewards, operating procedures, supervision, coworkers, the nature of the work, and communication (Lumley, Coetzee, Tladinyane, & Ferreira, 2011). Job satisfaction represents employees' feelings towards their jobs, and thus, job satisfaction is a function of the perceived relationship between employees' anticipations in relation to the job and what they gain from that job, as well as the meaning or value that employees attribute to their jobs (Ko, 2012).

Table 3
Population and sampling.

	2014	2015	2016	2017	2018
Participants	55	58	58	65	63
Population	76	76	76	74	85
Participation Percentage	72%	76%	76%	88%	74%

Table 4
Survey variables and survey items.

Variables	According to	Variable
Satisfaction with my research lines	Motivation (Şimşek et al., 2011)	Dependent
Satisfaction with my projects		Dependent
Satisfaction with my challenges		Dependent
Relationships within organization	Relationships with coworkers (Blustein, Kenna, Gill, & DeVoy, 2008; Grant, 2007; Duffy et al., 2015; Lumley et al., 2011)	Independent
Express opinions	Communication (Lumley et al., 2011)	Independent
Motivation	Maslow Motivation Theory (Maslow, 1943)	Independent
Recognition of carried out work	Intrinsic reward (Blustein et al., 2008; Grant, 2007; Duffy et al., 2015)	Independent
Contribution to my training	Individual needs and what the organization is providing (Cable & DeRue, 2002)	Independent
Commitment of resources		Independent
Performance measurement system	Nature of work and communication (Lumley et al., 2011)	Independent
Information on my objectives and tasks		Independent
Information on correct development of my work		Independent
Knowledge of the department's roadmap		Independent
Projects' management	Operating procedures (Lumley et al., 2011)	Independent

Table 5
Research study reliability and validity.

Year	Scale reliability statistics			Measure of sampling adequacy
	Mean	SD	Cronbach's α	KMO (Overall)
2014	2.99	0.466	0.895	0.769
2015	2.92	0.458	0.890	0.810
2016	2.88	0.479	0.887	0.810
2017	3.10	0.437	0.868	0.764
2018	3.11	0.434	0.842	0.745

Cable and DeRue (2002) reviewed the varying ways that subjective fit has been operationalized and measured and concluded that three components were integral to the overall assessment of fit: person-organization fit (P–O fit), needs-supplies fit (N–S fit), and demands-abilities fit (D-A fit). P–O fit refers to an overlap of personal and organizational values; N–S fit refers to what an individual needs and what the organization provides; and the D-A fit refers to how well a person's skills and abilities match the needs of the work environment. Cable and DeRue observed that each of these components is a unique factor in the overall assessment of subjective fit. A number of other later studies have used this framework to conceptualize and assess subjective fit (Rehfuss, Gambrell, & Meyer, 2012; Duffy, Autin, & Bott, 2015).

Job satisfaction is also linked to motivation. According to Maslow, motivation means "behaving with one's own desire and eagerness and making efforts for the purpose of achieving a specific goal" (Maslow, 1943). Motivation is defined as the process by which an employee's efforts are strengthened for, oriented to, and sustained toward attaining a goal (Robbins & Coulter, 2009; Kaya & Ceylan, 2014). This definition of motivation has three elements: energy, direction, and persistence. The common

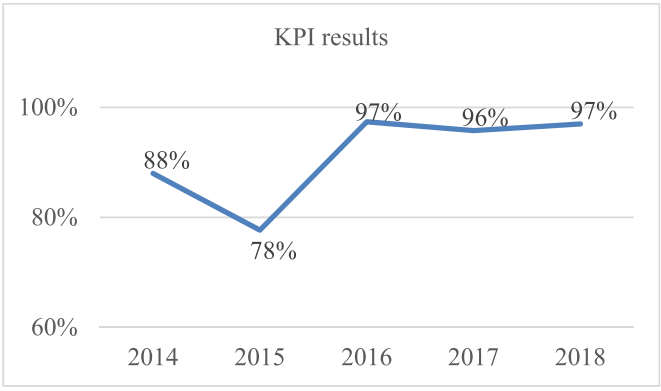

Fig. 3. RTO annual key performance indicators' results (2014–2018).

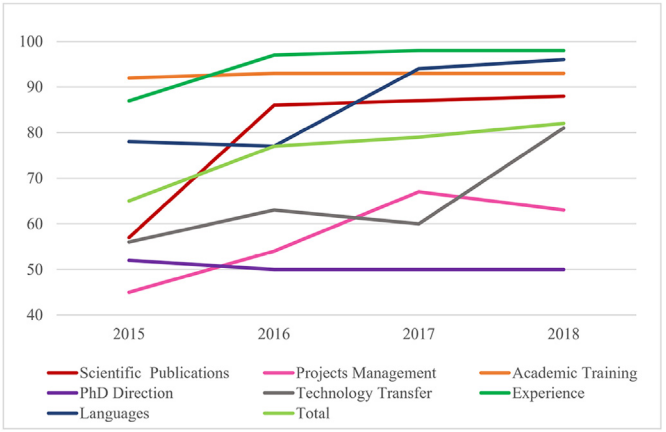

Fig. 4. Decree compliance (2015–2018).

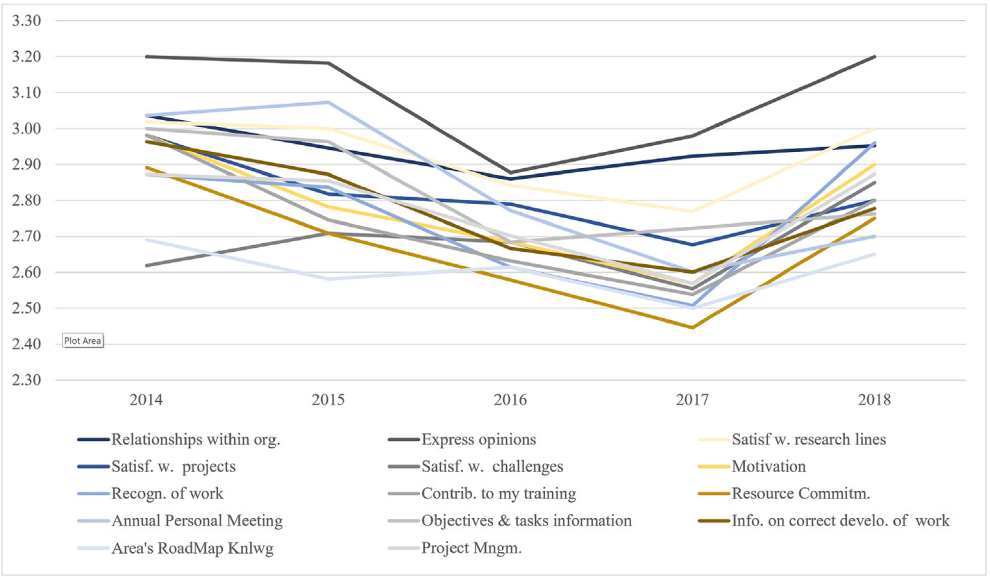

Fig. 5. Mean evolution (2014–2018).

Table 6
Multivariate test results.

		Relationships within org.			Express opinions			Motivation			Recognition of work			Contribution to my training		
Year	Stats	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges
2014	F	1.46	0.14	7.10	9.81	2.03	0.75	17.4	19.10	30.9	0.54	0.96	5.62	9.00	4.71	2.13
	p	0.23	0.72	0.01	0.00	0.16	0.39	<.001	<.001	<.001	0.47	0.33	0.02	0.00	0.04	0.15
2015	F	2.5 E−29	0.38	1.55	18.24	6.10	5.39	33.47	24.03	41	4.93	5.27	5.15	4.87	2.39	6.28
	p	1.00	0.54	0.22	<.001	0.02	0.03	<.001	<.001	<.001	0.03	0.03	0.03	0.03	0.13	0.02
2016	F	4.92	6.15	10.47	0.04	0.02	0.02	30.82	24.80	57.7	0.60	0.01	0.08	5.21	0.90	2.20
	p	0.03	0.02	0.00	0.85	0.89	0.90	<.001	<.001	<.001	0.44	0.92	0.78	0.03	0.35	0.15
2017	F	1.50	4.80	0.55	6.14	9.96	25.85	19.03	19.91	36.63	0.02	1.99	0.04	0.01	0.02	3.45
	p	0.23	0.03	0.46	0.02	0.00	<.001	<.001	<.001	<.001	0.90	0.17	0.84	0.92	0.90	0.07
2018	F	2.13	9.9E-04	1.87	17.49	34.71	15.86	1.25	7.04	7.67	2.00	0.02	27.32	0.00	0.32	2.62
	p	0.15	0.98	0.18	<.001	<.001	<.001	0.269	0.01	0.008	0.16	0.89	<.001	0.95	0.58	0.11

element of the definitions of motivation in the literature is that it affects human behavior, and as a result of this effect, guides the person toward certain actions (Şimşek, Akgemci, & Çelik, 2011). This study defines the concept of motivation as perception that one's personal preferences (values, needs, and skills) match what is being provided by the work environment.

Based on the two research questions cited in the introduction and on the above literature review, this study involves the following hypotheses:

Hypothesis 1. A new culture of organizational management based on a professional career development system within a holistic framework improve compliance with the Decree requirements.

Hypothesis 2. Human resources practices affect the job satisfaction of R&D personnel.

3. Method

3.1. Sample and data collection procedures

For the case study, a research population of RTO researchers was selected, and a survey was administered. A survey application was created online, prepared on the website, finalized, and sent to the participants via e-mail, and participation was anonymous and voluntary. Population was 76 researchers from 2014 to 2016, 74 in 2017 and 85 in 2018 (see Table 3).

Table 3 illustrates the number of participants out of the total population and the percentage of participation. The survey population excluded non-research staff (covered by a different survey outside the scope of Decree 109/2015) and directors (as they could positively influence the results). The participation of the research staff was, on average, 71% with the highest percentage in 2017 and the lowest in 2014. The sample for each year is representative of the population. In turn, half of the staff completing the survey recorded comments regarding improvements in human resources management.

Forty percent of the population were Ph.D. candidates, and the remainder were engineers; 35% were female, and the average age of the population was 33. The researchers are specialized in different fields, and all conducted research into software applications (information and communication technologies) in different sectors.

The organization's annual satisfaction questionnaire consists of 40 questions, covering seven areas of RTO operation. For this research project, 14 questions were selected from six different areas, covering a period from 2014 to 2018 (five years), and the questions were selected from previous studies on job satisfaction.

For all the survey items, a 4-point Likert scale was used, answers ranging from "strongly disagree" to "strongly agree." The data were collected from the administration department of the RTO and analyzed globally (by management) and by each department (results were delivered to each area director). This variable of job satisfaction is calculated using three different subscales: satisfaction with research lines, satisfaction with projects, and satisfaction with challenges faced.

3.2. Variables and empirical strategies

Based on the concepts described in the literature review, variables and items were selected from the annual satisfaction survey (Table 4). Table 4 also demonstrates the relationship between the area of inquiry and theory (the variables selected appear in the literature as influencing job satisfaction, as explained in the theory section). The questions were repeated in all the annual surveys. These items were chosen because they were most relevant to the conceptual framework on which the present study is based.

3.3. Research study reliability and validity

Using the data obtained from the surveys, reliability was assessed, and the validity was verified. To examine the relationship between items, an analysis of the items was performed (Table 5). Measurements were evaluated using Cronbach's

Resource Commitment			Annual Personal Meeting			Objectives & tasks information			Info. on correct develo. of work			Area's RoadMap Knowledge			Project Management		
Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges	Satisf w. research lines	Satisf. w. projects	Satisf. w. challenges
1.19	3.69	0.14	0.29	14.16	0.79	0.15	2.03	1.15	1.00	1.53	0.27	0.78	4.57	2.90	0.12	1.18	1.87
0.28	0.06	0.71	0.59	<.001	0.38	0.70	0.16	0.29	0.32	0.22	0.60	0.38	0.04	0.10	0.73	0.28	0.18
1.15	0.08	0.05	2.1E-04	0.56	0.00	6.97	8.21	2.54	9.2E-05	0.38	1.70	0.02	1.00	4.71	0.00	0.29	2.27
0.29	0.78	0.82	0.99	0.46	0.95	0.01	0.00	0.12	0.99	0.54	0.20	0.88	0.32	0.04	0.94	0.60	0.14
0.00	0.07	0.16	0.12	0.91	0.19	0.62	0.66	0.07	6.5E-04	0.54	0.08	4.66	0.18	1.57	0.50	0.01	6.33
0.97	0.79	0.69	0.73	0.34	0.67	0.44	0.42	0.79	0.98	0.47	0.77	0.04	0.68	0.22	0.49	0.92	0.02
3.81	2.00	4.07	0.78	2.76	0.23	3.2E-07	0.31	0.32	0.80	0.24	0.07	0.40	2.36	2.25	5.39	9.77	8.24
0.06	0.16	0.05	0.38	0.10	0.63	1.00	0.58	0.58	0.38	0.62	0.79	0.53	0.13	0.14	0.02	0.00	0.00
10.85	0.53	3.59	0.04	0.02	0.11	0.48	5.9E-04	5.08	0.22	0.75	3.03	1.13	6.56	0.97	0.09	25.76	30.96
0.00	0.47	0.06	0.85	0.88	0.74	0.49	0.98	0.03	0.65	0.39	0.09	0.29	0.01	0.33	0.77	<.001	<.001

alpha, and their reliability was tested. A review of all the alpha values demonstrated that all variables are higher than the threshold of 0.7 accepted in the literature, even without the extraction of the average variance (the lowest being 0.84). The research scale consisted of a total of 14 questions; 11 independent and 3 dependents. The Kaiser-Meyer-Olkin value, the most accurate measure of the validity of a scale, was determined to be at least 0.76, which is a good indicator of validity.

3.4. Multivariate test

A MANOVA analysis was performed to test the second hypothesis. This analysis illustrates the results of the multivariate test with Pillai's trace analysis (suitable for this study as the population was not large). Univariate tests with all independent and dependent variables for the five years of the study are also shown in section 4.2.

4. Findings and validated decisions

During these five years (2014–2018), the implementation of the career development system improved the achievement of key performance indicators for the RTO. Fig. 3 presents the progress of the key performance indicators in terms of the percentage of achievement. These figures were obtained by the RTO and audited by the Basque government. A transition period is apparent between 2014 and 2016, with positive progress after that, which stabilized in the last three years.

These results were analyzed for their percentage of Decree compliance in terms of professional development and job satisfaction. The discussion below demonstrates that both hypotheses were confirmed.

4.1. Hypothesis 1

The first hypotheses predicted that a new culture of organizational management based on a professional career development system, if implemented within a holistic framework would improve compliance with the Decree requirements.

As Fig. 4 illustrates, the percentage of the RTO's compliance with the requirements of Decree 109/2015 changes from 64% to 82% of the total number of researchers. The variable that improved the most during the four years is the number of scientific publications, which began at 58% achievement and ended at 91%. Measures introduced by the RTO to support the co-authorship of the publication of R&D projects, as well as increased resources for publication in indexed journals helped the most to achieve this result. Requirements that were difficult to achieve were doctoral theses and project management metrics (the variable that did not improve). In this case, training and rotation in the delegation of project management among the researchers were some of the measures taken. In general, it was possible to implement the requirements of the Decree and nearly 20% improvement was achieved. Although the number of R&D personnel at the RTO also increased by 20% (and thus the number of people affected by the Decree), implementation efforts were increased to compensate for this increase. One such adjustment was the implementation of new recruitment policies, which assured that new recruits would comply with and fulfill all the requirements of the Decree. This was a challenge for recruiters, who had to change their mindset, and for the recruits because some candidates were unsuccessful. Therefore, incorporating the people capability maturity model (holistic framework) into the professional career system resulted in an improvement in compliance with the requirements of the Decree, confirming Hypothesis 1.

4.2. Hypothesis 2

The second hypothesis predicted that human resources practices would affect the job satisfaction of R&D personnel. An examination of the global mean variation of this study demonstrates that global job satisfaction declined in 2015, increased moderately in 2016, and increased substantially in 2017 and 2018 when the final mean reached a record high for the satisfaction survey (Fig. 5).

The primary results of this study are as follows. Expressed opinions and motivation variables are statistically significant for every year, and motivation affects job satisfaction every year. Therefore, if the RTO can influence researchers' motivation, their satisfaction will improve. The expression of opinions within the organization had a positive effect on researchers' job satisfaction in 2015–2017 and 2018.

The contribution of training was significant in 2014 and 2015 and at the threshold of significance in 2016, with positive dependence in these periods. In 2017 and 2018, its influence diminished. In 2016, the RTO increased its annual training investment by more than 20%, and the researchers currently receive more training. The observed pattern can be explained by training being taken for granted instead of being a motivator.

In contrast, project management emerged as a significant variable affecting job satisfaction in 2017 and 2018. This phenomenon can be linked to recent recognitions of the RTO's. Additionally, according to researchers who have transferred into the industry, companies value researchers with management knowledge, as researchers can also include this knowledge in their CVs and increase their employability in the management of an internationally recognized centre. Another notable result is how annual feedback meetings were linked to project satisfaction in 2014, while the relationship was unobserved or was insignificant after that. These results can be visualized in Table 6.

5. Discussion

Every new human resources initiative has its effect on employees. Generally, changes are not welcome, but they are much less welcome if they occur in crucial fields such as career or performance evaluation. In this paper, the authors have contributed to the literature through the practical implementation of a strategy in the circumstances of an apparent contradiction: increasing employee job satisfaction in a scenario in which external requirements are demanding. This study is contiguous with the work of previous studies of employee job satisfaction (Abdulla et al., 2011; Judge et al., 2001) and career development (Kaya & Ceylan, 2014) in a particular organization. It also provides guidelines and requirements so that this system may be implemented by other organizations.

This system was developed based on a holistic framework that is derived in part from previous studies (Loyarte et al., 2018, 2020). These other studies also verified the kinds of changes the RTO underwent in the process of implementation as the organization reached a new balance, making it better prepared for the future. By implementing a professional development system, the researchers were more cognizant of both their career development goals and what they had already accomplished to that point. The implementation of the system was a responsibility shared with the researchers, giving them the freedom to manage their own careers through personalized monitoring that could be consulted in real-time.

The authors have also identified some limitations of the study. The primary limitation is that responding to the surveys was voluntary. This meant that the set of researchers who responded to the survey might have varied. The study also includes the input of different researchers because researcher turnover is high. As the project was primarily driven by Decree 109/2015, the RTO was not able to perform a study of the researchers' aspirations but had to follow the requirements of the Decree itself. Nonetheless, the Decree requirements must be considered at this point, as the government has performed a benchmarking of research careers in Europe and reviewed the centres as well as the professional career framework previously implemented by several centres in the Basque network.

Most similar career development and job satisfaction studies have been mentioned, but they have not been explained or compared in this study. In the literature review, career development programs and job satisfaction were explained as a cornerstone of this study although other different studies also exist.

According to practitioners, another limitation in the replicability is the implementation itself. In this case, five years of work is necessary, alongside the included management and consultancy. This is a major project that requires significant leadership, and subsequently, while the design and requirements are easy to replicate, the implementation requires time and effort.

6. Conclusions

Researchers are the cornerstone of the RTO. Their motivation, co-responsibility for their professional careers, and contributions to the centre's objectives are crucial. The five-year implementation results recommend a career development system, as it improved the RTO's production in a way that also allowed for an increase in researcher satisfaction.

The assumptions that motivated this research are related to how professional development might improve compliance with context requirements for RTOs and affect researchers' job satisfaction. The authors have focused on researchers at an RTO and investigated the progress of researcher satisfaction after career development changes as a result of new institutional requirements.

This study may be helpful to managers and scholars as a consolidated practice capable of guiding the implementation of an appropriate career development system as it elaborates on a practical framework with the following features. Each researcher's background, as well as an organization's requirements, forms part of the roadmap for the career development of RTO personnel. The framework links organizational objectives and researcher satisfaction to respond to employees' long-term plans (career development). The framework considers the context requirements of corporate strategies and researchers' contributions to assure their motivation and commitment to an RTO. Consequently, the five-year study demonstrates how key performance indicators properly balance the outcomes of decree compliance and researchers' job satisfaction. This study also helps to ensure that all employees are aware of areas of individual performance that could better contribute to the RTO's objectives.

Declaration of competing interest

The authors declare no conflicts of interest.

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References

Abdulla, J., Djebarni, R., & Mellahi, K. (2011). Determinants of job satisfaction in the UAE. *Personnel Review, 40*(1), 126–146. https://doi.org/10.1108/00483481111095555.

Akkermans, J., Brenninkmeijer, V., Huibers, M., & Blonk, R. W. (2013). Competencies for the contemporary career. *Journal of Career Development, 40*(3), 245–267. https://doi.org/10.1177/0894845312467501.

Arnold, J., & Cohen, L. (2008). The psychology of careers in industrial and organizational settings: A critical but appreciative analysis. In G. P. Hodgkinson, & J. K. Ford (Eds.), *International review of industrial and organizational psychology, 2008*. Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470773277.ch1, 1–44.

Blustein, D. L., Kenna, A. C., Gill, N., & DeVoy, J. E. (2008). The psychology of working: A new framework for counseling practice and public policy. *The Career Development Quarterly, 56*, 294–308. https://doi.org/10.1002/j.2161-0045.2008.tb00095.x.

Bremser, W. G., & Barsky, N. P. (2004). Utilizing the balanced scorecard for R&D performance measurement. *R & D Management, 34*(3), 229–238. https://doi.org/10.1111/j.1467-9310.2004.00335.x.

Cable, D., & DeRue, D. (2002). The convergent and discriminant validity of subjective fit perceptions. *Journal of Applied Psychology, 87*(5), 875–884. https://doi.org/10.1037//0021-9010.87.5.875.

Cartwright, S. (2005). *The Blackwell encyclopedia of management: Human resource management* (2nd.). Malden, MA: Blackwell Publishing Ltd.

Curtis, B., Hefley, W., & Miller, S. (2002). *The people capability maturity model: Guidelines for improving the workforce*. Boston, MA: Addison-Wesley Professional.

Demircioglu, M. A. (2018). Examining the effects of social media use on job satisfaction in the Australian public service: Testing self-determination theory. *Public Performance and Management Review, 41*(2), 300–327. https://doi.org/10.1080/15309576.2017.1400991.

Duffy, R., Autin, K., & Bott, E. (2015). Work volition and job satisfaction: Examining the role of work meaning and person-environment fit. *The Career Development Quarterly, 63*(2), 126–140. https://doi.org/10.1002/cdq.12009.

Granrose, C. S. (1997). A model of organizational careers in national contexts. In C. S. Granrose (Ed.), *The careers of business managers in East Asia* (pp. 12–36). Greenwood Publishing Group, Inc.

Grant, A. (2007). Relational job design and the motivation to make a prosocial difference. *Academy of Management Review, 32*(2), 393–417. https://doi.org/10.5465/amr.2007.24351328.

Hobfoll, S., Halbesleben, J., Neveu, J. P., & Westman, M. (2018). Conservation of resources in the organizational context: The reality of resources and their consequences. *Annual Review of Organizational Psychology and Organizational Behavior, 5*(1), 103–128. https://doi.org/10.1146/annurev-orgpsych-032117-104640.

Judge, T. A., Thoresen, C. J., Bono, J. E., & Patton, G. K. (2001). The job satisfaction–job performance relationship: A qualitative and quantitative review. *Psychological Bulletin, 127*(3), 376–407. https://doi.org/10.1037/0033-2909.127.3.376.

Kaya, Ç., & Ceylan, B. (2014). An empirical study on the role of career development programs in organizations and organizational commitment on job satisfaction of employees. *American Journal of Business and Management, 3*(3), 178–191. https://doi.org/10.11634/216796061403551.

Ko, W. (2012). The relationships among professional competence, job satisfaction, and career development confidence for chefs in Taiwan. *International Journal of Hospitality Management, 31*(3), 1004–1011. https://doi.org/10.1016/j.ijhm.2011.12.004.

Lee, C., & Bruvold, N. (2003). Creating value for employees: Investment in employee development. *International Journal of Human Resource Management, 14*(6), 981–1000. https://doi.org/10.1080/0958519032000106173.

Litano, M., & Major, D. (2016). Facilitating a whole-life approach to career development. *Journal of Career Development, 43*(1), 52–65. https://doi.org/10.1177/0894845315569303.

Loyarte, E., Garcia-Olaizola, I., Marcos, G., Moral, M., Gurrutxaga, N., Florez-Esnal, J., et al. (2018). Model for calculating the intellectual capital of research centres. *Journal of Intellectual Capital, 19*(4), 787–813. https://doi.org/10.1108/JIC-01-2017-0021.

Loyarte, E., Garcia-Olaizola, I., Posada, J., Azúa, I., & Flórez-Esnal, J. (2020). Enhancing researchers' performance by building commitment to organizational results. *Research-Technology Management, 63*(2), 46–54. https://doi.org/10.1080/08956308.2020.1707010.

Lumley, E., Coetzee, M., Tladinyane, R., & Ferreira, N. (2011). Exploring the job satisfaction and organisational commitment of employees in the information technology environment. *Southern African Business Review, 15*(1), 100–118. Available on https://www.ajol.info/index.php/sabr/article/viewFile/76394/66852.

Malhotra, N., Smets, M., & Morris, T. (2016). Career pathing and innovation in professional service firms. *Academy of Management Perspectives, 30*(4), 369–383. https://doi.org/10.5465/amp.2012.0108.

Maslow, A. (1943). A theory of human motivation. *Psychological Review, 50*(4), 370–396. https://doi.org/10.1037/h0054346.

Olaya Escobar, E. S., Berbegal-Mirabent, J., Alegre, I., & Duarte Velasco, O. G. (2017). Researchers' willingness to engage in knowledge and technology transfer activities: An exploration of the underlying motivations. *R & D Management, 47*(5), 715–726. https://doi.org/10.1111/radm.12263.

Rehfuss, M., Gambrell, C., & Meyer, D. (2012). Counselors perceived person–environment fit and career satisfaction. *The Career Development Quarterly, 60*(2), 145–151. https://doi.org/10.1002/j.2161-0045.2012.00012.x.

Robbins, S., & Coulter, M. (2009). *Management* (10th ed.). Prentice Hall.

Şimşek, M., Akgemci, T., & Çelik, A. (2011). *An introduction to behavioral science and behavior in organizations* (7th ed.). Ankara: Öz Baran Offset Matbaacılık.

Spurk, D., Hirschi, A., & Dries, N. (2018). Antecedents and outcomes of objective versus subjective career success: Competing perspectives and future directions. *Journal of Management, 45*(1), 35–69. https://doi.org/10.1177/0149206318786563.

Taylor, J. (2014). Public service motivation, relational job design, and job satisfaction. *Public Administration, 92*(4), 902–918. https://doi.org/10.1111/j.1467-9299.2012.02108.x.

Van der Heijde, C. M., & van der Heijden, B. (2006). A competence-based and multidimensional operationalization and measurement of employability. *Human Resource Management, 45*(3), 449–476. https://doi.org/10.1002/hrm.20119.

Basque Government. (2014). PCTI Euskadi 2020 (Plan for Science, Technology, and Innovation). Available on https://www.euskadi.eus/gobierno-vasco/pcti-2020/. (Accessed 13 November 2019).

Decree 109/2015 23 June. (2015). Decree for the Reorganization of the Basque Science, Technology and Innovation Network.. Available on https://www.euskadi.eus/gobierno-vasco/-/decreto/decreto-1092015-de-23-de-junio-por-el-que-se-regula-y-actualiza-la-composicion-de-la-red-vasca-de-ciencia-tecnologia-e-innovacion/.

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Enhancing Researchers' Performance by Building Commitment to Organizational Results

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FEATURE ARTICLE

Enhancing Researchers' Performance by Building Commitment to Organizational Results

A new rating system offers a way to measure researchers' performance objectively and support corporate results.

Edurne Loyarte-López, Igor García-Olaizola, Jorge Posada, Iñaki Azúa, and Julián Flórez-Esnal

OVERVIEW: Performance measurement systems are a fundamental concern for R&D managers and executives. The main challenge is ensuring that R&D managers can match organizational key performance indicators with researchers' interests. This article details a new approach to measuring the fuzzy parameter of researchers' performance. It presents a case study on the implementation of a rating system in a research technology organization and reports the results the system achieved, including researcher satisfaction. We describe which researcher skills were selected for rating, the evaluation criteria developed, and the data collection system that supported the rating process. The rating system was developed to be objective and acceptable to researchers, and to support achievement of desired corporate results. We present lessons learned from implementation over four years.

KEYWORDS: Performance measurement system, Balanced scorecard, Key performance indicators

Performance measurement is critical in knowledge-based organizations where R&D is a key strategic value (Chiesa et al. 2009; Laliene and Ojanen 2015; Qin and Du 2018). Yet researcher performance is a fuzzy parameter. The uncertainty associated with R&D activities makes evaluating individual researchers relative to other functions complex, given that some required activities are unknown initially, the value created by those activities is uncertain, and failure to achieve desired outcomes may be acceptable. Measuring performance is difficult in the absence of timely data or when there are unknowns associated with R&D efforts, such as in projects whose initial scope is unclear.

Although performance evaluation exists in all organizations, finding a system designed for employees that is devoid of subjectivities or comparative grievances is difficult. Objectivity should be an essential attribute of a performance measurement rating system—with the objectivity accepted by employees and oriented to corporate results so that

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employees see a fair and value-oriented system they can contribute to in the organization.

We propose a performance measurement system for researchers in a research technology organization in the information and communication technologies sector. The rating system we developed achieves our aims of being objective, acceptable to researchers, and helping achieve desired corporate results. Selecting appropriate indicators is a cornerstone (Samsonowa 2012) because these indicators need to respond to organizational results and enable researchers to realize their potential (Goffee and Jones 2009).

Background

Performance measurement is not new, but few prior studies explain the complete process, including indicators, employees' reactions, and lessons learned. Within performance measurement, researcher performance is a fuzzy parameter. We conducted a literature search focused on organizations with similarities to the research technology organization used in this study, together with the main authors and newest studies in the field (Agostino et al. 2012; Ambalangodage, Fie, and Gunawardana 2015; Chiesa et al. 2009; Henttonnen, Ojanen, and Puumalainen 2016; Qin and Du 2018). We also conducted a benchmarking process to review the strengths and weaknesses of international research organizations, particularly regarding their methodologies.

We learned that similar organizations use feedback interviews, which tend to be subjective, for performance measurement and that selection of adequate indicators is the main problem in measuring performance. We also found that balanced scorecard is a common technique for performance evaluation in R&D organizations and others and that the People Capability Maturity Model (PCMM) is a powerful model to implement a solid human resources system to measure employees' job satisfaction and organizational results.

Balanced scorecard is a management system designed to align the organization with its strategy at all levels (Bobadilla and Gilbert 2017; Kaplan and Norton 2001; Spano et al. 2016). After the balanced scorecard model is formulated at the corporate level, it is cascaded downward to strategic business units and support departments. Full implementation of the balanced scorecard model requires cascading down to the individual level, giving each person a perspective of his or her role in strategy implementation (Bremser and Barsky 2004).

The PCMM is a roadmap for implementing practices that continuously improve the capability of an organization's workforce. It was published by Carnegie Melon University in 1995 as the foundation for a model of best practices for managing and developing an organization's workforce (Curtis, Hefley, and Miller 2001). The PCMM matrix begins at level 2 because that is the management minimum; according to the model's designers, an organization at level 1 is not

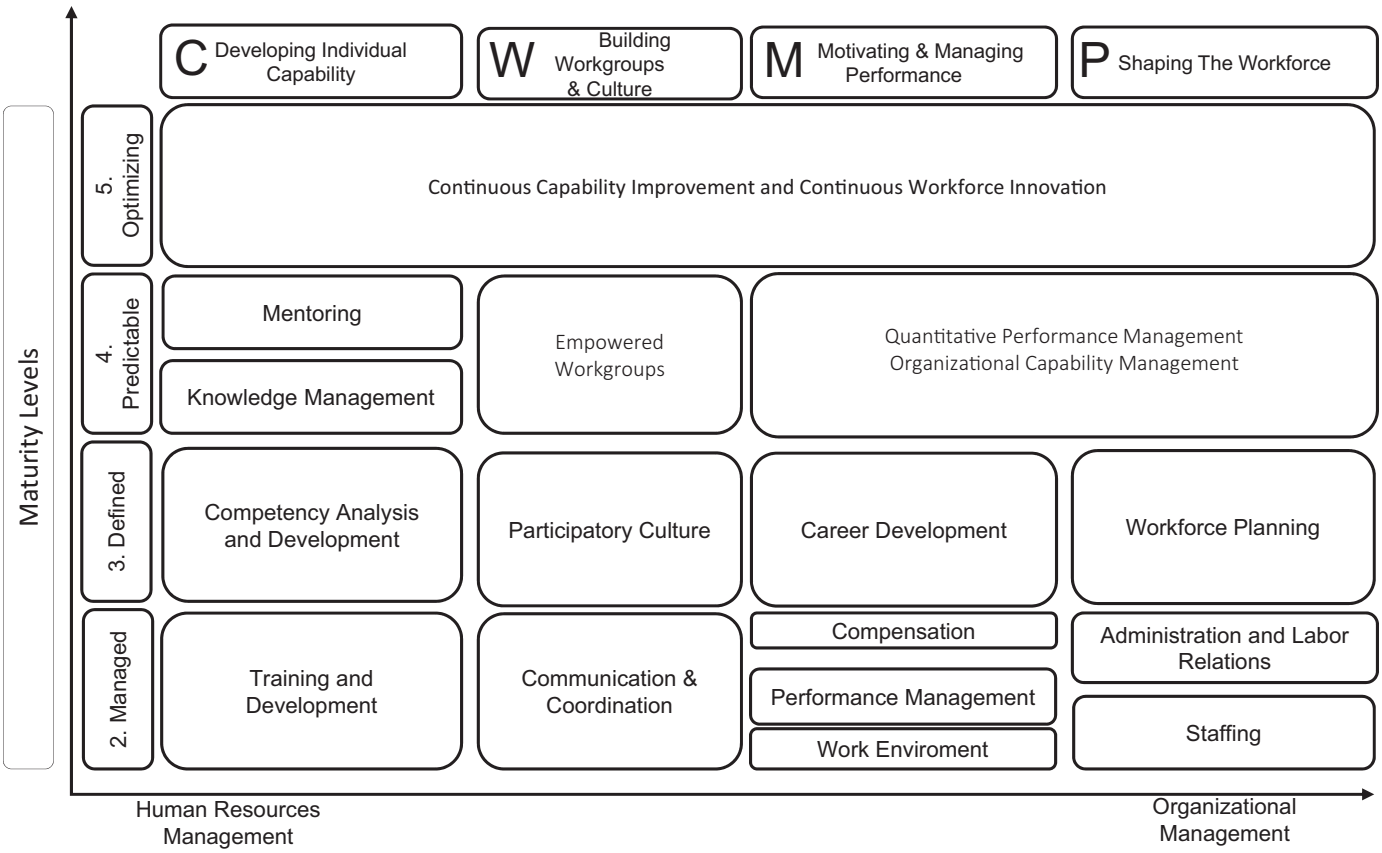

FIGURE 1. People capability maturity model

Researchers need a roadmap for their work performance and must be able to see how their performance contributes to the organization or positively impacts applied research.

managing its resources at all. As the level rises, the processes to be implemented are more complex and the organization becomes more mature (Figure 1). A process area (each box) in the PCMM model is a cluster of related practices that, when performed collectively, satisfy a set of goals that contribute to the capability gained by achieving a maturity level. In this sense, a performance measurement system is at the second level but depends on areas at different levels, such as career development, competency analysis, and training (Curtis, Hefley, and Miller 2001). The PCMM model gives coherence among processes, helping researchers to understand corporate objectives and their value in the organization.

Drawing from our research, we developed a rating system based on balanced scorecard and the PCMM to measure researcher performance. Our rating system focused on objectivity, researcher acceptance, and desired corporate results. We conducted a longitudinal study in which we tracked implementation of our rating system over four years. For the study, we followed the balanced scorecard meticulously to guarantee the objectivity of the system and to clarify the individual value to the organization. The indicators by which the departments and individuals are measured are a direct extract of corporate indicators. For instance, "indexed publications" is an organizational, departmental, and individual indicator. The rating system methodology for R&D performance measurement successfully balances organizational and individual interests (Figure 2).

Case Study

This case study focuses on a research technology organization located in the Basque Country of Spain. Its main business activity is R&D aimed at enhancing the innovative performance of customers and society. The organization is a nonprofit foundation with different research outputs, ranging from basic research to experimental prototype development (technology readiness levels 3–7). The organization's financing comes from a variety of sources: 50 percent from industrial contract projects and 50 percent from collaborative research projects submitted as a competitive bid for partial funding by public administrations, such as the European Commission and the Basque Government.

The organization has 120 employees, 45 of whom hold doctoral degrees, working in a variety of technology domains. The organization publishes more than 60 scientific publications each year and holds several patents. It also develops R&D software libraries that are sold based on licenses to industrial users.

Performance measurement is difficult for this organization because it does not research directly with the final users or apply its research in the marketplace, and therefore it cannot determine an absolute value for its R&D efforts (Loyarte et al. 2018; Rincón Diaz and Albors Garrigós 2017). This difficulty to measure is common for nonprofit research organizations that generate research but do not commercially exploit it.

The Researchers

Since researchers are pillars in the study organization, their needs and profiles must be considered in the rating system. The rating system aims—objectivity, researcher acceptance, and desired corporate results—are matched against researchers' needs and profile as follows:

- *Objectivity:* Due to the analytic and rational profile of researchers, the rating system must contain an objective model with transparent criteria. Overly qualitative

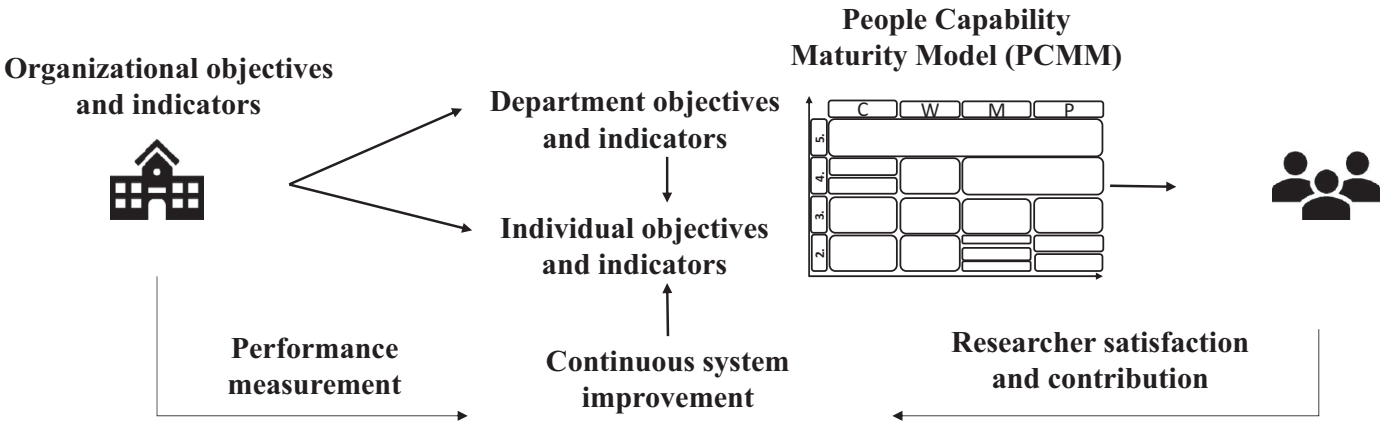

FIGURE 2. Rating system methodology

evaluations are unsuitable for researchers who need data to evidence their individual performance. Researchers should not have the impression that appraisal criteria depend on the department or area in which they are working at the time of evaluation. Evaluations should be consistent over time (Kahneman 2013; Meehl 2013).

- *Researchers' acceptance:* Researchers are experts in software development, so the rating system has to be technologically attractive and function correctly.
- *Results:* Researchers need a roadmap for their work performance and, above all, must be able to see how their performance contributes to the organization or positively impacts applied research. This is particularly important for R&D professionals. Researchers may feel frustrated if their research is not used or does not contribute to the industrial domain and society.

Performance Measurement Rating System

Our rating system integrated insights from the literature review and benchmarking as well as the performance measurement system's objectives of objectivity, researchers' acceptance, and organizational results. We designed the system in line with the following requirements:

- *Objectivity:* Selection of the indicators should be meticulous and based on careful study (Samsonowa 2012). In addition, a multidisciplinary researcher model should be established encompassing scientific, technological, management, and opportunity creation skills, so that researchers are measured against the same criteria. Evaluation is based on real data that are results oriented: records of hours spent working in projects, accepted publications and proposals, documented client satisfaction, and other relevant criteria.
- *Researchers' acceptance:* The evaluation process must be tied to other processes, such as professional career development, compensation, and training. The human resources management model is essential for consistency in organizational practices, which explains why the case study organization chose the PCMM (Curtis, Hefley, and Miller 2001). In terms of strategy, an organization should train its workforce to acquire the various competencies required to perform its business activities (Dangmei 2017).
- *Results:* Performance evaluation should follow the balanced scorecard criteria so that researchers can clearly see their contribution to the organization and share their results. The system is oriented toward results, rather than effort or other, more subjective criteria that depend on the work capacity and vision of each person. The organization administers the system, which gathers data and converts them into points according to the contribution to the organization.

According to balanced scorecard practices, the organization cascades its objectives to different departments. Researchers, as individuals, contribute to these objectives, so individual performance measurement is another cascaded practice that researchers need to understand. Both capabilities and career development need to be focused on meeting the organization's objectives, so the PCMM is the cornerstone. The organization checks performance against the global and departmental objectives every six months, while individual performance is reviewed annually. These evaluations enable the organization to identify the challenges and set new objectives and action plans. For personnel, the results of individual performance reviews impact different aspects (Figure 3).

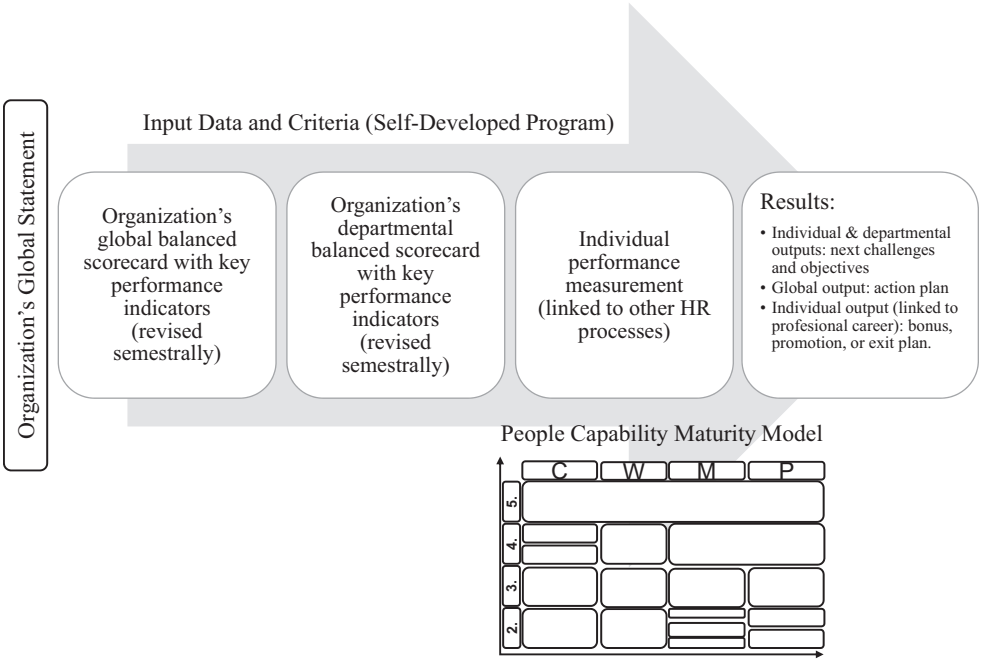

FIGURE 3. Performance measurement system process

Evaluation Criteria and Indicators

The department head evaluates all researchers using the indicators in the annual review. All quantitative indicators are calculated automatically. The first step is for the researcher and department head to examine separately the indicator results and submit their individual evaluations. Once both evaluations have been completed, the results are merged into a single, final evaluation by discussing each of the scores during a feedback interview. The final version is sent to the human resources director with the interview minutes as well as the challenges and objectives for the next year. The human resources director closes the process after revision and approval.

In this process, researchers share responsibility for their challenges, performance, and professional career against a set of clear guidelines. Being conscious of these factors influences researchers' satisfaction, commitment, and concerns. As an employee, researchers need to cultivate and apply the following skills:

- Publications and patents
- Management/execution of projects
- Generation of R&D opportunities
- Technology transfer
- People management/leadership
- Communication

The first two skills are measured quantitatively, and the others are measured qualitatively. Each researcher and department head evaluates the qualitative indicators and reach agreement during the feedback interview. Each criterion has a definition and different items that must be evaluated in assessing the researcher. The indicators for scientific publications and patents are accompanied by the scoring per item. The score for each category is also capped at a maximum total score—this cap applies regardless of the total summed score for all the indicators (Table 1). The system also includes indicators for the management and execution of projects (Table 2). During the annual performance evaluation process, any colleague may provide feedback about an assessed colleague. This feedback reaches the evaluated researcher, the department head, and management.

The combined maximum for quantitatively measured skills is 1,200 points, which translates into 70 percent of the evaluation score. The other 30 percent is formed by the qualitatively measured skills, for which the combined maximum is 1,600 points (400 each). The final evaluation score is weighted from 0 to 10. A score below 5 indicates that performance can be improved; a score higher than 8.5 indicates that performance is extraordinary (eligible for a bonus payment). By way of example, one indexed publication is scored at 70 points, but if the researcher also publishes in Q1, the total score rises to 170 points. Regarding project management and execution, creativity is evaluated by means of ideas generated, with scores calculated based on hours spent working in projects. For example, if a researcher's idea has finally become a project, the hours spent on the idea are converted into points (conversion rate: 100 percent). We present the scoring of European projects of more than €100,000 per year and industrial projects of more than €250,000 per year. Smaller projects have a 15 percent lower conversion rate.

Data are collected and structured in a self-developed program. The software is the platform for the management of projects, objectives and indicators, workloads, employee performance evaluations, personnel administration, management system logs, analytical accounting, and the organization's clients and suppliers. The data are collected mainly from daily releases, publications, patents, software libraries, and customers' feedback. The program transforms the data automatically into evaluation indicators according to the selected criteria. The systems department verifies and validates program outcomes every six months. This

TABLE 1. Publications and patents

Indicator	Quantity	Maximum Point Value
Co-management of thesis	No. Theses	100
New patent applications	No. Patents	100
New patent applications in collaboration with other Basque science network agents	No. Patents	100
Indexed publications	No. Articles	70
Indexed publications (Q1)	No. Articles	100
Indexed publications (Q2, Q3, Q4)	No. Articles	70
Indexed publications in collaboration with other Basque science network agents	No. Articles	100
Indexed publications with two or more coauthors	No. Articles	50
Relevant development of registered software (more than 200 hours worked on the registered software)	No. Registered software	100
Researcher's doctoral thesis defended during current year	No. Thesis	100
Special awards for scientific publications (best paper, best thesis, first prize, etc.)	No. Articles	100
Maximum Possible Points from Indicators		400

TABLE 2. Management and execution of projects*

Indicator	Quantity	Points Available
Accepted proposals in which the researcher is the idea's main initiator (hours allocated to the idea)	Total hours	100%^
Internal leader in the preparation of accepted proposals (hours allocated to the proposal)	Total hours	100%^
General project leader (hours allocated to the management task)	Total hours	100%^
Work package leader	Total hours	85%^
Technical hours dedicated to projects	Total hours	65%^
Internal leader of European project achieving highest score (1) from European Commission	No. Projects	250
Participant of European projects achieving highest score (1) from European Commission	No. Projects	100
Verifiable transfer of registered software technology (invoiced)	No. Registered software	100
Clients' documented evidence regarding researchers' performance in the project	No. Projects	100

*Researchers earn points for European projects valued at more than €100,000 per year and industrial projects valued at more than €250,000 per year.

^Points Awarded = Hours x Percentage

program allows performance evaluations to be objective and automatically calculated, which greatly optimizes the process and removes the subjectivity that could harm researchers' motivation. The information can also be obtained in real time.

Validating Rating System Results

Individual performance evaluation is connected to promotions, bonuses, and exit plans. Therefore, the rating system must be reasonable—it is invalid if most reseachers obtain the maximun 10 points or fail to obtain five points. The rating system is also designed to provide a balanced appraisal of each researcher's annual performance in terms of scientific articles and patents, project management, and development and management skills. It recognizes, for example, that some researchers are strong in publishing while others are more skilled at management.

Following the aforementioned aspects, the case study organization built a visual analytics platform to validate the rating system results and identify areas for improvement.

TABLE 3. Case study organization results

Challenge		Indicator		%	U	AG	PM				Results			
							O	P	D	I	2015	2016	2017	2018
R&D activity mix		% Expenditure	Fundamental Research	10	%	10	X	X	X		7.1	22.4	11.7	10.6
			Industrial Research			60	X	X	X		58.9	48.2	60.0	55.0
			Experimental Development			30	X	X	X		34.0	29.4	28.3	34.4
Specialization		% Expenditure of total R&D activities	R&D in Advanced Manufacturing	10	%	75	X	X	X		69.18	72.08	73.44	78.10
			R&D in Energy											
			R&D in Bioscience and Health											
Excellence	Fundamental Research	Indexed scientific publications		2	No.	20	X		X	X	51.0	31.2	33.0	34.4
		Q1 scientific publications		2	No.	10	X		X	X	9.0	6.7	8.8	10.4
	Industrial Research	European patent applications		12	No.	3	X		X	X	3.0	2.9	2.7	7.8
		Income from licenses and patents		12	€k	400	X		X	X	3.8	122.5	310.1	334.4
	Experimental Development	Startups' turnover		4	€k	100	X				183.9	26.8	309.9	610.2
		Impact on the company's invoicing		8	€k	5000	X		X	X	3695.5	3588.2	4236.5	5338.2
Model of relationship	Transfer to market	Private funding (% in the Basque Country)		5	%	40	X		X	X	41.1	46.4	39.3	42.2
		Total private funding %		5	%	50	X			X	46.4	51.8	43.3	48.1
		Researchers transferred to Basque companies		5	No.	12	X		X		4.5	0.0	11.1	5.9
	Cooperation among Basque science network agents	Co-direction of PhD thesis		5	No.	8	X		X	X	7.0	8.6	11.5	10.4
		Coauthorship of scientific publications		5	No.	8	X		X	X	15.0	14.3	7.9	17.4
		Co-invention of patents		5	No.	1	X		X	X	0.0	0.0	0.9	1.7
	International cooperation	% of international public funding		5	%	15	X	X	X	X	23.7	14.9	16.6	21.3
		International projects with participation of Basque companies		5	No.	10	X	X	X		3.0	0.0	4.4	5.2
TOTAL GOAL ACHIEVEMENT (%)											**77.7**	**79.2**	**95.8**	**97.4**
ANNUAL INCOME (€m)											**7.6**	**8.4**	**9.8**	**11.9**
FTE											**100**	**104**	**116**	**120**

AG: Annual Goal; BS&TN: Basque Science and Technology Network; PM: Performance Measurement; O: Organizational; P: Project; D: Department; I: individual; U: measurement units.

Visual analytics is a big data technology that presents complex data graphically from a variety of perspectives so that the data are simple to view, understand, and analyze. Visual analytics systems provide a quick, intuitive, and qualitative view while allowing for deeper and quantitative analysis. The rating system data can be viewed in order by category, department, by each indicator, and in 3-D. The organization also works with representations where the statistical properties of each indicator can be observed. The platform also enables analysis of data and model parameters. Any change in data, model, or user action is synchronously applied in all plots to keep a coherent representation. Viewing the ratings system data in various formats helps validate the rating system results and improve users' system knowledge. The platform is adaptable to the organization and its researchers.

Results

Using the rating system, the organization saw continuous improvement from 2015, when the model was first implemented, to 2018 (Table 3). Total goals achievement rose from 77.7 percent in 2015 to 97.4 percent in 2018. Each indicator is associated with a challenge and contains an objective as well as the designated percentage of the total performance score. It also shows at what level of the organization the indicator has been implemented for its evaluation. The results improve considerably over the four documented years, and the organization's growth is notable in terms of annual income (from €7.6 million in 2015 to €11.9m in 2018) and staff (from 100 full-time equivalents in 2015 to 120 in 2018). The transfer of researchers is an indicator for the organization because this activity is mandated by the Basque Government as a means of transferring technology to companies (DECRETO 109/2015). Initially, the most difficult indicators in terms of achievement were incomes from licenses and patents (in 2015 income from these sources was just €3,800), and the co-invention of patents and international projects with participation of Basque companies. The data demonstrate the achievement of one of the system's objectives: driving the desired corporate results.

Researcher Satisfaction

Through the researchers' real-time monitoring of their own evaluation indicators and the continuous improvement of the rating system according to their suggestions, the rating system has achieved high scores in annual satisfaction surveys, in which a representative sample of the researcher population participates. Satisfaction scores for performance measurement, work environment, lines of research, challenges, and motivation have improved annually (Table 4). It should be noted that the increase in transfer rate is due to the researchers' transfer indicator: the organization should transfer 12 of every 100 researchers annually. The result is below the indicator in every year.

Particularly noteworthy is the substantial increase in performance measurement satisfaction from 59 percent to 80 percent, together with the 5 percent increase in researchers' motivation.

TABLE 4. Researcher satisfaction survey results

	2015	2016	2017	2018
Participants	58	58	65	63
Population	76	76	74	85
% participation	76%	76%	88%	74%
Researcher transfer rate	2%	7%	3%	11%
Absenteeism (parental leave)	1.00%	1.23%	1.18%	1.20%
Satisfaction				
Performance measurement system	59%	62%	63%	80%
Working environment	74%	73%	77%	78%
Research lines	78%	75%	82%	84%
Annual challenges	75%	75%	76%	79%
Motivation	78%	76%	80%	82%

These data demonstrate the achievement of the second objective of the ratings system: researchers' acceptance.

Discussion

The longitudinal study yielded several important findings and lessons learned and exposed difficulties and limitations. Four years is a significant time frame in which to test and evaluate the efficacy of the rating system we developed. Our goals were to make the rating system objective, acceptable to researchers, and help achieve desired corporate results. Our proposed rating system allows researchers to easily compare among themselves with respect to the same requirements, thereby eliminating subjective comparisons. We learned that managing dissent is key—the system collapses if exceptions are made (for example, staff with badly executed time records or evaluation scoring without documentation). Whenever changes are implemented, expect resistance from staff who fight harder to prevent losses than to achieve gains (Kahneman 2013). It is also crucial to prevent gaps among employees growing over time. Bridge any detected gaps as soon as possible to ensure a coherent system. To this end, department heads and managers have undergone high-level training in the case study organization.

PCMM implementation proved valuable in enabling researchers to know their career development and comprehend the cohesion and coherence of the performance measurement process with all other human resources processes. For example, if scientific publications are important for the organization and are set as an individual performance measurement indicator, training in writing publications and opportunities for scientific progression in researchers' career development are needed to ensure coherence and achieve the desired results.

Commitment to a multidisciplinary profile for all researchers develops because the system has fostered the

emergence of adaptable and multiskilled researchers, with opportunities to develop soft skills they might not have applied before. This multidisciplinary profile also enhances their employability in the organization. Evaluation is based on everyday work. Scoring based on the time spent on accepted projects or accepted publications, both directly related to researchers' day-to-day work, is easily understood and carefully considered in managing their work. Some researchers in the case study organization have become highly qualified directors.

After four years of implementation, our results demonstrate the practical value of the rating system:

- 50 percent of transferred researchers set up their own company or gained management positions in relevant companies of the Basque Country, thus demonstrating their management competencies.
- 25 percent of the projects and 20 percent of the scientific publications involved inter-departmental collaboration (some even won best paper awards in indexed and highly rated journals).

The orientation toward acknowledging results, rather than effort, requires a shift in researchers' thinking and behavior. Researchers may work on European proposals that are not accepted or spend numerous hours on publications that get rejected. If an unaccepted European proposal or rejected publication receives points, the responsible researcher may not have to seek other methods to acquire points. Using our results-based rating system, researchers must look for other ways to earn points when their proposals and publications are rejected. The shift to results-based ratings may be a learning process for researchers.

Management as a required skillset for researchers' careers may also require a shift in thinking because generally researchers are not keen to undertake management activities. The ratings systems requires researchers to manage projects (to earn points), so the soft skills training is key to helping them understand the value of this skill. Developing skills in project management also enhances researchers' employability in the industry.

This research methodology has limitations, the most significant being single-case studies have limited potential for systematic generalization. Rather than generalize, our aim was to enrich the body of knowledge on the performance measurement process. While the balanced scorecard and the PCMM were cornerstones of this study, other tools exist. Another possible limitation is the implementation of the rating system. In this case study, four years of work were required, including management and consulting. This is a major project that requires significant leadership. The design and indicators are easy to replicate, but the implementation takes time and effort.

Implications for Practitioners, Managers, and Researchers

Our research contributes to management best practices and to the literature by offering consolidated guidance on how to implement an appropriate performance measurement system, including a practical rating system. The model is especially appropriate for research staff due to the indicators' adaptability and the program's usability. However, it can also be applied in other sectors, given that the same concepts can be used to design and objectively evaluate (with other indicators). With this model, we also found that researchers' motivation and co-responsibility for their professional careers and contributions to the organization's objectives are crucial for improving individual and organizational results.

The orientation toward acknowledging results, rather than effort, requires a shift in researchers' thinking and behavior.

This rating system methodology for R&D performance measurement balances organizational and individual interests and ensures objectivity. Original enterprise resource planning is used to give researchers access to their performance indicators and to enable them to track their evaluation in real time. The organization verified and validated the system over four years to improve it and then measured results using metrics for employee satisfaction and organizational results.

Conclusion

This research demonstrates how to measure researcher performance objectively. Our rating system avoids the subjectivity of different evaluators and ensures consistency in the scoring throughout the organization and over time. A performance evaluation system in the research sector does not suppress creativity, but rather channels it toward a shared commitment and aim—namely, the visible results (for example, in real technology transfer to companies). Consequently, this rating system enables organizations to be objective and fair with their employees in their performance evaluation, without impacting organizational results negatively. Such a system may be especially useful when efforts and outputs can be hard to measure, as is the case with organizations focused on R&D.

References

Agostino, D., Arena, M., Azzone, G., Dal Molin, M., and Masella, C. 2012. Developing a performance measurement system for public research centres. *International Journal of Business Science and Applied Management* 7(1): 43–60.

Ambalangodage, D., Fie, D., and Gunawardana, K. 2015. Consequences of performance measurement system: The case of Sri Lankan Water Board. *World Journal of Management* 6(2): 108–26. doi:10.21102/wjm.2015.09.62.08

Bobadilla, N., and Gilbert, P. 2017. Managing scientific and technical experts in R&D: Beyond tensions, conflicting logics and orders of worth. *R&D Management* 47(2): 223–35. doi:10.1111/radm.12189

Bremser, W., and Barsky, N. 2004. Utilizing the balanced scorecard for R&D performance measurement. *R&D Management* 34(3): 229–38. doi:10.1111/j.1467-9310.2004.00335.x

Chiesa, V., Frattini, F., Lazzarotti, V., and Manzini, R. 2009. Performance measurement of research and development activities. *European Journal of Innovation Management* 12(1): 25–61. doi:10.1108/14601060910928166

Curtis, B., Hefley, W., and Miller, S. 2001. *The People Capability Maturity Model. Guidelines for Improving the Workforce*. Boston: Addison-Wesley Professional.

Dangmei, J. 2017. People capability maturity model (P-CMM) facing the key HR challenges of MSME in India: A theoretical approach. *Asian Journal of Management* 8 (2): 132–136. doi:10.5958/2321-5763.2017.00022.1

DECRETO 109/2015, de 23 de junio, por el que se regula y actualiza la composición de la Red Vasca de Ciencia, Tecnología e Innovación. Basque Government. https://www.euskadi.eus/gobierno-vasco/-/decreto/decreto-1092015-de-23-de-junio-por-el-que-se-regula-y-actualiza-la-composicion-de-la-red-vasca-de-ciencia-tecnologia-e-innovacion/

Goffee, R., and Jones, G. 2009. *Clever: Leading Your Smartest, Most Creative People*. Cambridge: Harvard University Press.

Henttonen, K., Ojanen, V., and Puumalainen, K. 2016. Searching for appropriate performance measures for innovation and development projects. *R&D Management* 46 (5): 914–27. doi:10.1111/radm.12178

Kahneman, D. 2013. *Thinking, Fast and Slow*. New York, NY: Farrar, Straus and Giroux.

Kaplan, R., and Norton, D. 2001. Transforming the balanced scorecard from performance measurement to strategic management: Part I. *Accounting Horizons* 15(1): 87–104. doi:10.2308/acch.2001.15.1.87

Laliene, R., and Ojanen, V. 2015. R&D performance measurement: A process perspective revisited. In *2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 971–75. IEEE. doi:10.1109/IEEM.2015.7385793

Loyarte, E., Garcia-Olaizola, I., Marcos, G., Moral, M., Gurrutxaga, N., Florez-Esnal, J., and Azua, I. 2018. Model for calculating the intellectual capital of research centres. *Journal of Intellectual Capital* 19(4): 787–813. doi:10.1108/JIC-01-2017-0021

Meehl, P. E. 2013. *Clinical Versus Statistical Prediction: A Theoretical Analysis and a Review of the Evidence*. Echo Point Books & Media.

Qin, X., and Du, D. 2018. Measuring Universities' R&D performance in China's provinces: A multistage efficiency and effectiveness perspective. *Technology Analysis & Strategic Management* 30(12): 1392–1408. doi:10.1080/09537325.2018.1473849

Rincón Díaz, C., and Albors Garrigós, J. 2017. Research and technology organizations' mobilizers of the regional environment: Competitive strategies. *European Journal of Management and Business Economics* 26(2): 180–198. doi:10.1108/EJMBE-07-2017-011

Samsonowa, T. 2012. *Industrial Research Performance Management*. Heidelberg: Physica-Verlag HD. 10.1007/978-3-7908-2762-0.

Spano, R., Sarto, F., Caldarelli, A., and Vigano, R. 2016. Innovation & performance measurement: An adapted balanced scorecard. *International Journal of Business and Management* 11(6): 194–204. doi:10.5539/ijbm.v11n6p194