Journal of Information Systems Engineering and Management
2025, 10(34s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Machine Learning for Human Resource Management in the Public Sector: Early-Career Turnover Intention Prediction Model

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ARTICLE INFO

Received: 30 Dec 2024

Revised: 05 Feb 2025

Accepted: 25 Feb 2025

ABSTRACT

The study aims to develop an optimal turnover intention prediction model through training, including explanatory variables that have causal relationships with early-career turnover intention in the public sector. This study employs job-related factors, organization system factors, and socio-psychological factors, using the Public Employee Perception Survey data. According to the result, the random forest prediction model provides a better fit to predict early-career turnover intention and most variables of the importance index of turnover intention are P-O fit, P-J fit, satisfaction with the welfare benefits system, and HR, job satisfaction, autonomy, education, and prospects. This study provides policy implications and future direction to decrease early-career turnover intention in the public sector in South Korea.

Keywords: Turnover Intention, Machine Learning, Human Resource Management, Public Sector.

INTRODUCTION

Researchers in the fields of human resource management and organizational behavior consistently emphasize the importance of utilizing human resource. Peffer (1994), a renowned scholar in human resource management, argues that strategic human resource management is a crucial factor determining the success or failure of an organization and is largely decided by the operation of human resource management. The core issue of human resource management is securing and retaining top talented (Kim, 2003). The process of securing top talent and the attention and effort required to retain them are equally necessary. However, compared to the cost of hiring a single excellent employee, the cost of efforts to retain that employee receives significantly less attention even though there are significant loss of human capital and associated costs (Ongori, 2007). In particular, in the case of Korean public officials, due to high exam competition rates and low turnover rates, it has not been mentioned as a major issue (Kim, 2021).

Recently, the rapidly increasing turnover rate of Korean public officials and the declining competition rate have become issues. The Ministry of Personnel Management announced that the competition rate for the national level 9 civil service exam has continuously decreased from 82.2:1 in 2010 to 37.2:1 in 2020, and further to 21.8:1 in 2024. In addition, according to the statistics from the Government Employees Pension Service, the number of public officials resigning with less than three years of service increased from 4,712 in 2017 to 5,166 in 2018, 6,147 in 2019, and 8,442 in 2020. Among them, the resignation of newly appointed public officials with less than one year of service rose significantly from 951 in 2018 to 1,610 in 2020 (Yonhap News, 2022). It has been shown that along with turnover, the intention to leave is also increasing. About 34.2% of early-career public officials with five years or less of service expressed an intention to leave, which increased to 41.1% in 2020. This trend indicates that the younger the age and the shorter the service period, the higher the intention to leave (Korea Institute of Public Administration, 2022).

The outflow of talented public official is intensifying and many researchers have maintained that our society takes proactive responses. Consequently, there is an increasing attempt to analyze large volumes of data using new

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Journal of Information Systems Engineering and Management
2025, 10(34s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
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technologies to solve complex society problems and predict risk factors in advance (Chowdhury et al., 2023). In accordance with the trend, private companies, public enterprises, and public institutions have various attempts to utilize AI technology across all areas of human resource management. For example, Google and Amazon use AI algorithms in their hiring, evaluation, promotion, and downsizing selection processes. Japanese company SoftBank analyzed that by using IBM's Watson AI in the document screening of new employees, they reduced the time required for the traditional document review process by 75%, from 680 hours to 170 hours (Chosun Biz, 2017). Additionally, through Watson's Predictive Attrition Program, AI predicted employees at risk of leaving with 95% accuracy, and they minimized gaps caused by turnover through proactive hiring of replacement personnel (E-Today, 2019).

There are several limitations to human resource management, especially turnover, with the introduction of new technologies. First, there are no standards to address the issue of the AI black box phenomenon, where structural approaches are limited because AI algorithms are not disclosed. It is difficult to obtain learning and test data, and even when obtained, it takes a long time to process and refine the data, necessitating guidelines for data refinement and learning processes. Second, compared to the activation of AI utilization in human resource management in the private sector, the introduction of new technologies and human resource management in public institutions are at a very insufficient level (Cho et al., 2023). Although research in the fields of AI and human resource management is becoming active, the pace of technology utilization in the public sector is slow. Lastly, traditionally, research related to turnover prediction in Korea has been insufficient. While there are social and institutional differences compared to other countries, it is also because the market for experienced positions is not active. However, due to changes in the labor market environment and the increase in job-based pay transitions, there is a need for us to pay attention to turnover. Thus, this paper aims to identify factors influencing early-career turnover intention using machine learning.

THEORETICAL BACKGROUND

Turnover Intention

Concept of Turnover (Intention)

Turnover refers to all movements within an organization, such as transfers, redeployments, and promotions, as well as movements from outside to inside and vice versa. In a narrower sense, it refers only to movements from inside the organization to outside. Turnover is defined as the dynamic concept of physically moving from the organization where an individual stay (Price & Mueller, 1981) or as the act of withdrawal by members (Heinen et al., 2013; Tett & Meyer, 1993; Mobley, 1982). Turnover intention represents a conscious and deep intention or willingness to leave and is considered the final stage of perception regarding turnover (Mobley et al., 1978; Tett & Meyer, 1993). Numerous previous studies have empirically demonstrated a very high correlation between turnover intention and actual turnover, and turnover intention is often used as a surrogate variable for turnover in many studies (Batt & Valcour, 2003; Voigt & Hirst, 2015).

Turnover, in a broad sense, includes all movements within an organization such as transfers, redeployments, and promotions, as well as movements from outside to inside and vice versa. In a narrow sense, it refers only to movements from inside the organization to outside. Most prior research has understood and studied turnover in this narrow sense. Turnover is defined as a dynamic concept of physically moving from the organization where an individual stay (Price & Mueller, 1981), or as the act of withdrawal by members (Heinen et al., 2013; Tett & Meyer, 1993; Mobley, 1982). Turnover intention represents a conscious or intention and willingness to leave and is considered the final stage of perception regarding turnover (Mobley et al., 1978; Tett & Meyer, 1993). Numerous previous studies have empirically demonstrated a very high correlation between turnover intention and actual turnover, and turnover intention is often used as a surrogate variable for turnover in many studies (Batt & Valcour, 2003; Voigt & Hirst, 2015).

Turnover can be voluntary, where members sever their relationship with the organization due to personal factors such as age (Heinen et al., 2013), gender (Al Momani, 2017; Sousa-Poza & Sousa-Poza, 2007), tenure, marriage, pregnancy, migration, or organizational factors such as expectations from the organization, job stress (Arshadi & Damiri, 2013), job characteristics (Lee, 1995), poor working conditions, inadequate managerial support and

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Journal of Information Systems Engineering and Management
2025, 10(34s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
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leadership (Demirtas & Akdogan, 2015; Vecchio & Norris, 1996; Wells & Peachey, 2011). Involuntary turnover includes forced resignation, discharge, lay off, mandatory retirement, and forced retirement, where individuals are expelled from the organization against their will (Mobley, 1982). Most turnover-related research focuses on voluntary turnover (Bae & Kim, 2009). Among these, studies primarily address avoidable turnover due to causes that organizations can control. Organizations expect members to perform to the best of their abilities, while members wish to satisfy their needs for salary, promotion, and working conditions. When this relationship is not balanced, organizational members may move to another organization that better meets their needs, which is called avoidable turnover. Avoidable turnover can be classified into planned-avoidable turnover caused by relationship failures, poor performance, rule violations, and unplanned-avoidable turnover due to low wages, dissatisfaction with working conditions, grievances, job mismatch, job insecurity, and lack of promotion. Additionally, there is planned-unavoidable turnover due to contract completion, mandatory retirement, and unplanned-unavoidable turnover due to health issues, geographic relocation, career changes, and job dissatisfaction (Bluedorn, 1978).

In the public sector, where employment is secured, voluntary turnover due to personal decisions is more common than involuntary turnover such as forced retirement or lay off. Particularly, turnover among early-career employees is prevalent among the youth, who tend to seek jobs multiple times compared to middle-aged individuals due to experiencing various life changes such as independence, marriage, childbirth, and parenting (Brzinsky-Fay, 2007). Early-career employees have generally completed basic work-related education and training, and it is the stage where they can contribute substantially to the organization with their capabilities and expertise (Kim, 2003). Meanwhile, turnover among early-career employees leads to vacancies, which can disrupt work performance and affect organizational productivity (Kim, 2021). Research on turnover began to gain attention as unemployment emerged as a socio-pathological phenomenon (Hong, 2018), but most studies focus on the private sector. Park and Ryu (2008) found that job satisfaction and skill fit, along with organizational structural factors such as working hours, affect the turnover intention of early-career college graduates. According to Jung and Lee's (2010) study, organizational structural factors such as salary, overtime pay, bonuses, personnel systems, vacations, company holidays, job factors like work autonomy and content, and socio-psychological factors such as interpersonal relationships and individual growth potential are determinants of early retirement. Lee, Park, and Lee (2014) revealed that organizational structural features like income, welfare working conditions, and job-related factors such as job-major match are variables explaining the turnover intentions of young people. Moon and Hong (2017) analyzed that organizational structural factors like wages, employment types, and socio-psychological factors such as future prospects are significant factors affecting youth turnover. Lee, Cho, and Song (2020) analyzed factors such as average monthly starting salary, job satisfaction, employment stability satisfaction, and working environment satisfaction from organization system factors, and job satisfaction, job aptitude match from job-related factors, and interpersonal relationship satisfaction and personal growth potential satisfaction from socio-psychological factors to predict the turnover intentions of early-career employees. Kim and Kwon (2022) analyzed that job-related factors such as job satisfaction and socio-psychological factors influence the turnover of the MZ generation.

Early-Career Turnover Intention

The turnover of early-career employees in public institutions has recently become severe, raising concerns about significant losses for the public sector and the nation as a whole. The average preparation period to enter the public sector is reported to be 1 year and 6 months, with the time taken being approximately 16.9 months for those in their twenties and 20.2 months for those in their thirties (Segye-Ilbo, 2021). College students or graduates spend a considerable amount of time and money to enter public service, but after a few years, they may have dissatisfaction with the public organizations and intend to leave or leave, resulting in both direct and indirect costs as well as opportunity costs for their previous efforts (Kim, 2003). While it can be a process of searching for a job that suits them, frequent organizational departures of personnel responsible for the organization's future make labor skills difficult and have more severe negative impacts on organizational effectiveness. During the period from when a member starts to feel dissatisfied with the organization (t0) to the point of leaving the organization (t1), they lose interest in their job, and productivity declines. Additionally, from the point of turnover (t1) to the period until a replacement is hired (t2), the duties of the departing member remain vacant or are shared among other members. Finally, from hiring a replacement (t2) until the end (t3), costs are incurred for training and adapting the replacement

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to achieve the performance level previously attained by the departed member. Therefore, it is necessary to identify the factors influencing turnover and for organizations to take proactive measures to address frequent turnover (Kim & Ahn, 2012).

Recently, with the early-career turnover of the MZ generation from the public sector becoming a major topic, related studies have conducted to find factors influencing turnover rate. Cho (2021) have confirmed the significance of the moderating effect of the MZ generation and found that job-related factors such as job satisfaction and job stress, as well as organizational structural factors such as organizational commitment and compensation satisfaction, affect turnover intention. Seo and Kang (2022) have found that job-related factors such as regular workload, organizational structural factors such as compensation satisfaction, and socio-psychological factors such as stress influence the turnover intention of MZ public officials. The study conducted by Ji and Song (2021) analyzed intrinsic and extrinsic motivations affecting turnover intention by generation. Choi et al. (2022) analyzed that for the younger generation, not only the fit between person, organization, and job but also the absence of training programs to enhance competencies serve as moderating conditions affecting turnover intention.

Previous studies have mainly focused on identifying factors influencing the turnover intention of public officials or examining factors affecting the early turnover intention of early-career individuals. While these studies are meaningful, it is challenging to find research that compares the turnover intentions of public officials with the turnover intentions of early-career public officials. Additionally, studies establishing optimal prediction models for turnover intention and early career turnover intention using machine learning are rare. Therefore, this study aims to examine whether there are differences in the factors influencing turnover intention and early career turnover intention

Key Factors Influencing Turnover Intention

Job-Related Factors

Key factors influencing turnover intention include fitness, such as Person-Organization Fit, Person-Environment Fit, Person-Job Fit as a factor influencing turnover rates. Person-Organization Fit (P-O Fit) is defined as the congruence between an individual and an organization when either party fulfills what the other requires or when they share similar fundamental characteristics (Kristof, 1996). It also refers to the degree to which the organization's values, goals, and personality align with those of the individual (Lauver & Kristof, 2001), or the congruence between an individual's personality and the organizational climate (Bowen et al., 1991). Fit is considered to occur when the individual and the organization provide what the other desires, or when the individual is sufficiently satisfied with the resources provided by the organization. Person-Environment Fit (P-E Fit) refers to the positive alignment or congruence that occurs when an individual's characteristics match with their work environment. From the perspective of Person-Environment Fit, organizational performance and human resource management can be understood as a series of processes that involve selecting, placing, and training individuals who fit the organization. This is aimed at integrating the inherent values of individuals and fulfilling the requirements expected from them. Person-Job Fit (P-J Fit) can be defined as the extent to which an individual possesses the knowledge, skills, and abilities necessary to perform a job (Edwards, 1991), or as the alignment between an individual's desires and the characteristics of the job (Edwards, 1991). The extent to which an individual feels they fit with their job and the extent to which they feel they fit with the organization are different concepts. Therefore, elements related to the organization itself and those related to the job should be conceptually distinguished (Kristof, 1996).

In addition, job satisfaction is defined as a combination of beliefs related to organizational employees hold about their job (McCann et al., 2009). Robbins (2003) defines job satisfaction as a general attitude toward one's job, while Ryu et al. (2012) define job satisfaction as a positive emotional state experienced through job experiences. It was found that higher the alignment between job content and their major in undergraduate, and the more individuals perceive themselves as performing tasks with greater autonomy than their educational level, the higher their job satisfaction, which is associated with a lower turnover rate (Ahn & Lee, 2015; Park & Chung, 2019).

Organization System Factors

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Journal of Information Systems Engineering and Management
2025, 10(34s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
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Employees may perceive organizational decision-making as unfair if they discover unfair organizational decisions, if information related to organizational decisions is not disclosed, if employee opinions are not reflected in decision-making, or if they cannot challenge organizational decisions. This perceived unfairness can influence turnover intention (Han, 2019).

Welfare benefits system satisfaction and perception of fairness in HR system, such as salary and rewards are the variables influencing turnover rate (Park & Chung, 2019). The presence of various policies for work-life balance, their utilization rates, and satisfaction levels are factors that influence turnover rates. Welfare benefits system includes use of parental leave, childcare facilities, and flexible work arrangements. Eom (2008) has found that salary has a negative effect on early-career turnover intention.

Moynihan and Landuyt (2008) have found that fairness of HR system is one of the key factors on turnover intention. HR system is related to salary rewards, and promotion. According to their study, turnover intention decreases as salary and perceived fairness of salary increase, and as opportunities for promotion based on performance are provided.

Socio-Psychological Factors

Dissatisfaction with the future prospects of public service or a low social reputation of public servants can increase turnover intention (Park & Chung, 2019; Han, 2019) On the other hand, dissatisfaction with the low social reputation of public servants have no impact on turnover intention in small business firm (Eom, 2008).

Higher satisfaction with job training and more adequate provision of job training reduce turnover rates. Job training can enhance individual job performance and increase a sense of job accomplishment. If sufficient training is provided in organization to increase job capabilities, job satisfaction will increase and turnover intention will decrease.

According to the Cotton & Tuttle (1986)'s meta-analysis, key factors influence on turnover intention are relationship between employees and leaders. Park (2006) also analyzed that psychological burnout has a positive impact on turnover intention. Moreover, Rho and Choi (2018) have found that communication has moderating effect on the relationship between job-related factors and turnover intention.

Individual Characteristic Factors

According to the Moynihan & Landuyt (2008)'s study, individual characteristics have an influence on turnover intention. Individual characteristics includes age and Marriage. Turnover intention decreases when there is a family primary earner and as the number of family members increases. In addition, individual characteristics factor include gender, working hours (Park & Ryu, 2008) and rank, education (Han, 2019), and children under 19, and so forth (Park & Chung, 2019). In summary, it is as shown in [Table 1] below.

Table 1: Explanatory Variables for (Early-Career) Turnover Intention

Job-Related Factors	Organizational System Factors	Socio-Psychological Factors	Individual Characteristics
Job Satisfaction, Person-Organization Fit, Person-Environment Fit, Person-Job Fit, Job-Skill Fit, Job-Aptitude Fit, Job-Major Fit, Job Training Satisfaction,	Organizational Type, Organizational Size, Workplace Satisfaction, Monthly Average Starting Salary, Wage Satisfaction, Working Hours Satisfaction, Satisfaction with Bonuses and Welfare Benefits,	Personal Development Potential, Future Prospects, Job Reputation Satisfaction, Social Reputation Satisfaction, Interpersonal Relationship Satisfaction	Gender, Age, Tenure, Marriage, Pregnancy, Relocation, Presence of Minor Children, Working Hours, Job Rank,

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e-ISSN: 2468-4376
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Job-Related Factors	Organizational System Factors	Socio-Psychological Factors	Individual Characteristics
Job Autonomy, Authority, Skill Level	Work Environment Satisfaction, HR System Satisfaction, Employment Stability		Educational Background

METHOD

Turnover Prediction and Machine Learning Research

Prior studies on job turnover have utilized the traditional econometric logistic regression model. The greatest advantage of logistic regression is the stability of the model. However, it has the drawbacks of providing a linear decision boundary and not automatically considering interaction terms between variables (Oh et al., 2017). In other words, logistic regression focuses on estimating and testing correlation coefficients to analyze causal relationships. On the other hand, machine learning models aim to maximize the prediction accuracy for the dependent variable.

Random forest is known for its ability to flexibly adjust the complexity of the model, thereby achieving relatively high predictive performance by reducing errors even when many variables are included, through sufficient training processes (Korea Bank, 2019). As a non-parametric method, random forest does not require assumptions of homoscedasticity or linearity, making analysis easier. It is less sensitive to outliers and shows very high predictive power even with many explanatory variables. However, it has the disadvantage of lacking theoretical explanation and being difficult to interpret (Oh et al., 2017). Studies exploring the employment or early turnover prediction and determining factors of new college graduates in the private sector using random forest are readily available (e.g., Choi & Min, 2018; Lee, Cho & Song, 2020)

Moreover, there are studies on model prediction using Support Vector Machines (SVM), invented by Cortes and Vapnik (1995). The advantage of SVM is that it is not significantly affected by noise in the data and does not overfit, resulting in high predictive power. However, it has the drawback of being difficult to set the tuning parameters of the model, which can lead to different interpretations. Recently, there have been many studies researching turnover prediction models using SVM (e.g., Park & Lee, 2021; Lee et al., 2021).

The Naive Bayes algorithm, a representative of probability-based machine learning algorithms, operates on the naive assumption that each feature of the data is independent of the others. It functions on the philosophy of determining which label the data is most likely to be classified under when new input is provided. Bayes Formula is an important theorem, meaning that we can estimate the probability of an unknown future event through already established probabilities. Despite the naive assumption that all independent variables are independent, the algorithm performs quite well in practice, showing particularly strong performance in document classification problems. However, it is difficult to apply to data where the assumption of independence is hard to justify or in other types of classification problems.

Based on the review of Random Forest, SVM, and Naive Bayes analysis methods, another aim of this study is to develop predictive models. By comparing these three techniques, the study seeks to select the method that offers better predictions and to conduct precise and in-depth analyses to establish the optimal prediction model for the public sector, which can help prevent turnover in South Korea.

Data and Method

This study utilizes the Public Employee Perception Survey data (2017-2023) from the Korea Institute of Public Administration, considering the continuity of the data-set. Data prior to 2017 is not used due to its lower consistency with recent survey items, as it was a perception survey before being nationally approved statistics. Although data from 2017 to 2023 is included, time was not considered a significant factor, so it was not included as a variable.

In this study, descriptive statistics analysis was conducted using the Stata program to examine the demographic characteristics of the subjects of analysis. Predictive models for forecasting the turnover intention of public officials

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Journal of Information Systems Engineering and Management
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e-ISSN: 2468-4376
https://www.jisem-journal.com/

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and the early turnover intention of early-career public officials were built and compared using the Python program. After confirming whether the developed prediction models reliably predict turnover intention and early turnover intention, a predictive importance index was derived to explore the factors determining these intentions. Finally, a Partial Dependence Plot (PDP) was presented to examine the detailed relationships between the top variables in the predictive importance for turnover and early turnover intention, and early turnover, using the PDP package. '

Variables

Based on the survey items, the study aims to develop an optimal turnover intention prediction model through training, including explanatory variables that have causal relationships with early-career turnover intention in the public sector, as extracted from previous research.

This study is composed of three main categories—job-related factors, organizational system factors, and socio-psychological factors—as well as personal characteristic factors as control variables. Thus, the independent variables are composed of measurement indicators, which include three main categories and 14 items as explanatory variables (see [Table 2] below).

Job-related factors include perception of fitness and job characteristics. Perception of fitness consists of person-organization fit, person-environment fit, and person-job fit, while job characteristics include job satisfaction, workload, and perception of job autonomy. Organization system factors comprise the perception of the fairness of rules and regulation of organization, satisfaction with welfare benefits, and satisfaction with the pay and rewards. Socio-psychological factors include personal factors and reputation. Personal factors consist of future prospects related to personal development potential, satisfaction with training, and satisfaction with interpersonal relationships, while reputation includes social reputation. Individual characteristics as control variables include gender, age, marriage, children (under 19), working hours, rank, and education.

Early-career turnover of public officials is operationally defined as having a tenure of less than five years. According to Article 32 of the Public Officials Pension Act in South Korea, the regulations for applying retirement lump-sum payments are divided for those with a tenure of at least one month but less than five years and those with a tenure of five years to less than twenty years, and the amounts are calculated accordingly. The (early career) turnover intention of public officials in Korea is to evaluate and compare the Random Forest prediction model, SVM, and Naive Bayes, in order to select the model that best predicts early career turnover intention in the public sector in South Korea.

Table 2: Variables

Main Category		**Indicators**	**Sub-Indicators**	
			Items	**Questionnaires (items)**
Dependent Variable		Turnover Intention		Turnover Intention
Independent Variables	Job-Related Factors	Perception of Fitness	P-O Fit	Organizational Commitment (4)
			P-E Fit	Work Environment Satisfaction (3)
			P-J Fit	Job Stress (7)
		Perception of Job Characteristics	Job Satisfaction	Job Satisfaction Perception (3)
			Workload	Workload Perception
			Autonomy	Job Autonomy and Authority Satisfaction (3)
	Organizational System Factors		Perception of Fairness in Rules and Regulations	Decision Making Process
			Welfare Benefits System	Satisfaction with Welfare Benefits System (3)

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Journal of Information Systems Engineering and Management
2025, 10(34s)
e-ISSN: 2468-4376
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			HR	Salary and Rewards Satisfaction (4)
	Socio-Psychological Factors	Satisfaction	Future Prospects	Personal Development Potential (3)
			Training	Training Opportunity (3)
			Relationship	Communication (2)
		Reputation	Org. Social Reputation	Public Office Reputation
Control Variables	Individual Characteristics		Gender, Age, Marriage, Children (under 19), Working Hours, Rank, Education	

RESULT

Demographics

Over the seven years of the Public Employee Perception Survey data (2017-2023), there are a total of 32,314 respondents. Among them, 12,049 respondents showed turnover intention. According to the classification criteria of this study, respondents who showed turnover intentions of public officials after five years of employment were excluded, resulting in a total of 3,656 respondents who had early career turnover intentions of public officials within five years of employment.

Table 3: Target Classification

	No Turnover Intention		**Turnover Intention**	
			Turnover Intention	**Early-Career Turnover Intention**
Total	Employed within 5 years & no turnover intention	Employed more than 5 years & no turnover intention	Turnover intention after more than 5 years of employment	Turnover intention within 5 years of employment
32,314	4,155	16,110	8,393	3,656

The demographic characteristics of the analysis are shown in the table below. There are 6,658 males and 5,391 females who have an intention to leave after working for more than five years. The gender ratio of respondents with an intention to leave early within five years is 1,703 males and 1,953 females. Regarding marital status among respondents with an intention to early-career turnover within five years, 2,814 are unmarried, and 842 have a spouse.

Among the respondents with early-career turnover intentions, 3,269 had no children under 19 years old, 238 had one child, 132 had two, and 17 had three. The total working hours for respondents with early-career turnover intentions within five years were as follows: less than 35 hours for 17 respondents, 35 to less than 40 hours for 4 respondents, 40 to less than 45 hours for 1,143 respondents, 45 to less than 50 hours for 779 respondents, and 50 hours or more for 1,713 respondents.

Table 4: Demographics Characteristics

Category		**Total**	**Turnover Intention**	**Early-Career Turnover Intention**
Total		32,314(100%)	8,393(100%)	3,656(100%)
Gender	Male	18,933(58.6%)	4,955(59.0%)	1,703(46.6%)
	Female	13,381(41.4%)	3,438(41.0%)	1,953(53.4%)
Marriage	No spouse	10,570(32.7%)	1,966(23.4%)	2,814(77.0%)
	Has spouse	21,744(67.3%)	6,427(76.6%)	842(23.0%)
	None	16,620(51.4%)	3,466(41.3%)	3,269(89.4%)

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Journal of Information Systems Engineering and Management
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e-ISSN: 2468-4376
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Children (under 19)	One	6,637(20.5%)	2,029(21.2%)	238(6.5%)
	Two	8,071(25.0%)	2,588(30.8%)	132(3.6%)
	Three	926(2.9%)	293(3.5%)	17(0.5%)
	Four	53(0.2%)	15(0.2%)	0(0.0%)
	Five	7(0%)	2(0.0%)	0(0%)
Working Hours	less than 35 hours	94(0.3%)	15(0.2%)	17(0.5%)
	35~40 hours	60(0.2%)	7(0.0%)	4(0.1%)
	40~45 hours	9,619(29.8%)	2,242(26.7%)	1,143(31.3%)
	45~50 hours	7,140(22.1%)	1,708(20.4%)	779(21.3%)
	over 50 hours	15,401(47.7%)	4,421(52.7%)	1,713(46.9%)

Predicted Model Performance

In the case of the prediction model developed through machine learning, cross-validation is performed using validation data, allowing the model's predictive power to be evaluated through performance indicators (Lee et al., 2020; Hong, 2020; Shmueli, 2010). Prediction model produces accuracy, precision, recall, and F1 score. These metrics are used to evaluate the performance of models. Accuracy measures how many data are correctly classified out of the total instances. Precision indicates the proportion of true positive predictions among all positive predictions, while recall measures the proportion of true positives identified out of all actual positives. The F1 score is the harmonic measures of precision and recall, offering a balance between the two metrics.

According to the analysis, the model predicting civil servants' turnover intention showed that the Random Forest model had the highest accuracy (71.47%), followed by the SVM model (70.71%), and the Naive Bayes model recorded the lowest accuracy (68.44%). In terms of precision for predicting civil servants' turnover intention, the SVM model was the highest (71.61%), followed by the Random Forest model (68.31%), and the Naive Bayes model was the lowest (59.25%). Regarding recall, the Naive Bayes model had the highest rate (57.05%), followed by the Random Forest model (50.95%), and the SVM model recorded the lowest rate (39.32%). Considering the F1 score calculated from precision and recall along with accuracy, the Random Forest model is deemed the most suitable for predicting civil servants' turnover intention.

For predicting early-career civil servants' turnover intention, the SVM model showed the highest accuracy (71.59%), followed by the Random Forest model (71.15%), and the Naive Bayes model had the lowest accuracy (67.88%). In terms of precision for predicting early-career turnover intention, the SVM model was the highest (72.39%), followed by the Random Forest model (69.96%), and the Naive Bayes model was the lowest (63.60%). Regarding recall for predicting early turnover intention, the Naive Bayes model was the highest (70.33%), followed by the Random Forest model (65.18%), and the SVM model was the lowest (61.70%). Considering the F1 score calculated from precision and recall along with accuracy, the Random Forest model is considered to be the most suitable. Therefore, the Random Forest model demonstrated high predictive accuracy for both the turnover intention prediction model and the early-career turnover intention prediction model for early career civil servants. The results are shown in the table below.

Table 5: Result of Model Performance

		Accuracy	**Precision**	**Recall**	**F1 score**
Turnover Intention	Random Forest	71.47%	68.31%	50.95%	58.34%
	SVM	70.71%	71.61%	39.32%	50.77%
	Naive Bayes	68.44%	59.25%	57.05%	58.13%
	Random Forest	71.15%	69.96%	65.18%	67.48%
	SVM	71.59%	72.39%	61.70%	66.61%

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Journal of Information Systems Engineering and Management
2025, 10(34s)
e-ISSN: 2468-4376
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Early-Career Turnover Intention	Naive Bayes	67.88%	63.60%	70.33%	66.80%

Variable of Importance Index

The variable importance index based on random forests considers interaction between variables. This study produces importance index in a random forest model indicates the significance of each feature in predicting the turnover intention. This index helps in understanding the predictive power of each feature and can be used for feature selection, model interpretation, and improving model performance by focusing on the most important variables.

In this study, job-related factors are mostly ranked in top importance. Perception of fitness, as one of the job-related factors, P-O fit and P-J fit are the most remarkable variables in predicting turnover intention in the public sector in South Korea. Organizational system factors, such as satisfaction with welfare benefits system and HR are ranked top 3rd and 4th in predicting turnover intention. Perception of job characteristics, such as job satisfaction and autonomy are ranked top 5th and 6th in prediction of turnover intention in the public sector in South Korea. Education is ranked top 7th, while workload of perception of job characteristic is ranked top 8th.

Regarding early-career turnover intention, most variables of importance index of turnover intention has similar pattern with variables of importance index of early-career turnover intention. Job-related factors, such as P-O fit and P-J fit are also ranked in top importance for prediction model of early-career turnover intention. Organizational system factors, such as satisfaction with welfare benefits system and HR are ranked top 3rd and 4th in predicting early-career turnover intention. Perception of job characteristics, such as job satisfaction and autonomy are ranked top 5th and 6th in prediction of early-career turnover intention in the public sector in South Korea. Education is ranked top 7th, while future prospects of Socio-Psychological factor is ranked top 8th. Most important variables between turnover intention and early-career turnover intention are similar. On the other hand, personal development within their organization has been identified as highly important factor influencing early-career civil servants' turnover intention.

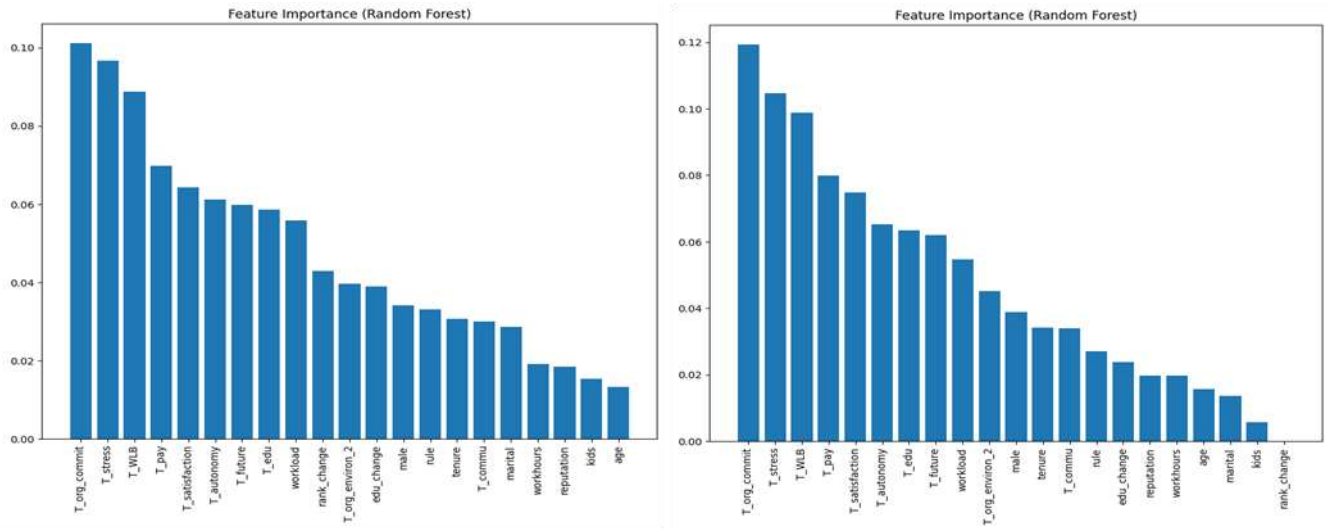

Figure 1. Variable of Importance Index of Non-Early Career(left) & Early Career(right) Turnover Intention

Partial Dependence Plot

The relationship between the predicted and the explanatory variables was examined through the Partial Dependence Plot (PDP) of the Random Forest. The partial dependence for each explanatory variable is shown by calculating the predicted probability of the response variable after averaging out the effects of other variables in the entire model (Hastie et al., 2009). The X-axis of the partial dependence plot represents the range of the explanatory variable, while the Y-axis represents the range of the marginal effect of the explanatory variable on the response variable. To identify the detailed patterns of the key determinants predicting turnover intention and early turnover intention, PDP plots

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Journal of Information Systems Engineering and Management
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e-ISSN: 2468-4376
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for the top 10 variables in the importance index were derived using the PDP package. All job-related factors were included in the top 10 variables in the importance index. Job-related factors can be considered to have a very significant impact on turnover intention and early-career turnover intention compared to organization system and socio-psychological factors.

All three items related to fit among job-related factors were included. The higher the perception of organizational commitment, which indicates person-organization fit, the lower both turnover intention and early-career turnover intention were found to be. The patterns of organizational commitment perception and turnover intention, as well as early-career turnover intention, were similar. Additionally, the higher the satisfaction with the work environment, indicating person-environment fit, the lower both turnover intention and early-career turnover intention were found to be. However, since the slope rapidly declines after an early turnover intention of 20, it can be seen that a slight increase in person-environment fit can significantly reduce turnover intention among early-career individuals. Lastly, regarding job-related factors, perceptions related to job stress, which indicate person-job fit, were found to increase both turnover intention and early-career turnover intention. This means that the higher the stress a person experiences in their job, the higher both turnover intention and early-career turnover intention become (See Figure 2).

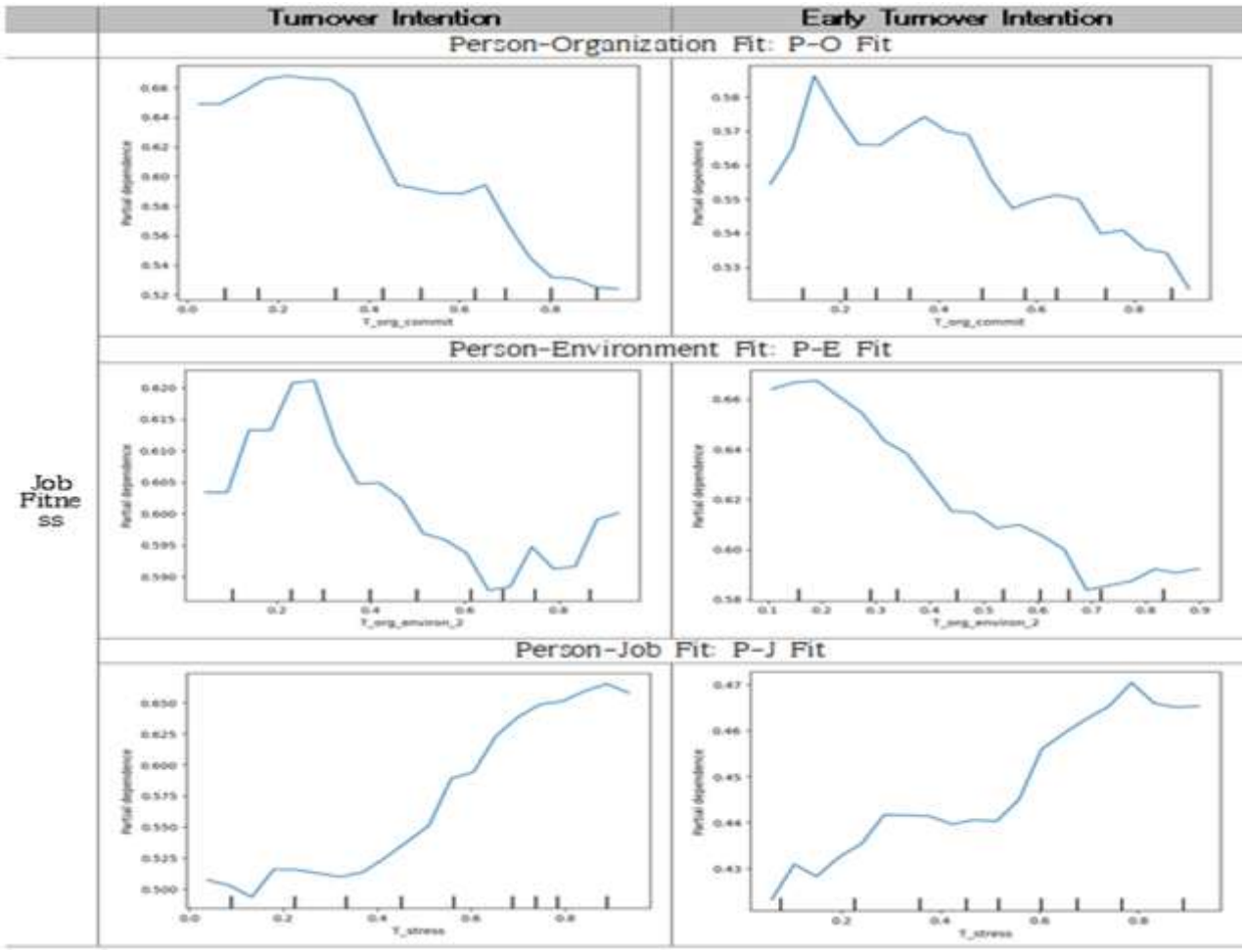

Figure 2. PDP Result-Job Fitness

Among job-related factors, job characteristics such as job satisfaction, workload, and perception of job autonomy were included in the top 10 variables in the importance index. Higher job satisfaction showed a trend of decreasing turnover intention and early-career turnover intention. However, early-career individuals appeared to react more sensitively to job satisfaction, with turnover intention significantly decreasing when satisfaction scores were above approximately 40 points. The more one feels the workload is heavy, the higher the turnover intention and early

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e-ISSN: 2468-4376
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turnover intention tend to be. For early-career individuals, turnover intention increased rapidly when the perception of excessive workload was above approximately 50 points. Regarding job autonomy, both lack of autonomy and excessive autonomy were associated with higher turnover and early turnover intention. In other words, a valley-shaped graph appeared, indicating that turnover and early-career turnover intention decreases when members feel they have a moderate level of job autonomy. For early-career individuals, turnover intention was low when they felt autonomy in the range of about 40 to 70 points, while for the overall group, turnover intention was low when they felt autonomy in the range of about 20 to 40 points. This suggests that autonomy should neither be too low nor too high (See Figure 3).

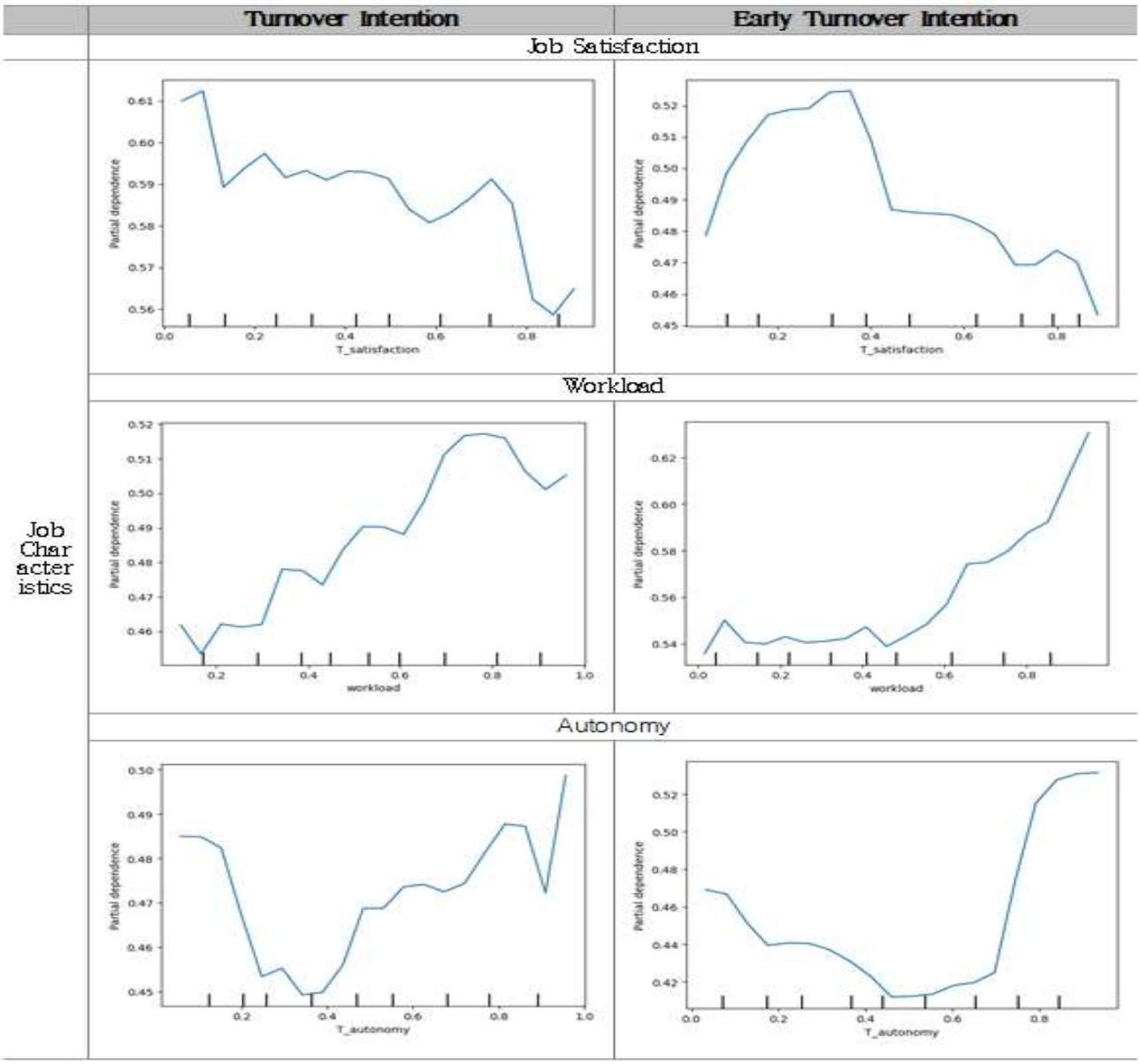

Figure 3. PDP Result-Job Characteristic

Among the top 10 variables in the importance index, organization system factors include welfare systems, and pay and rewards. The higher the satisfaction with welfare systems and the higher the compensation, the more turnover intention and early-career turnover intention tend to decrease. However, the graph for turnover intention among early-career individuals shows a steep decline at lower levels of satisfaction with welfare systems, and pay and rewards. This suggests that early-career individuals respond more sensitively to improvements in welfare systems, pay, and rewards (Figure 4).

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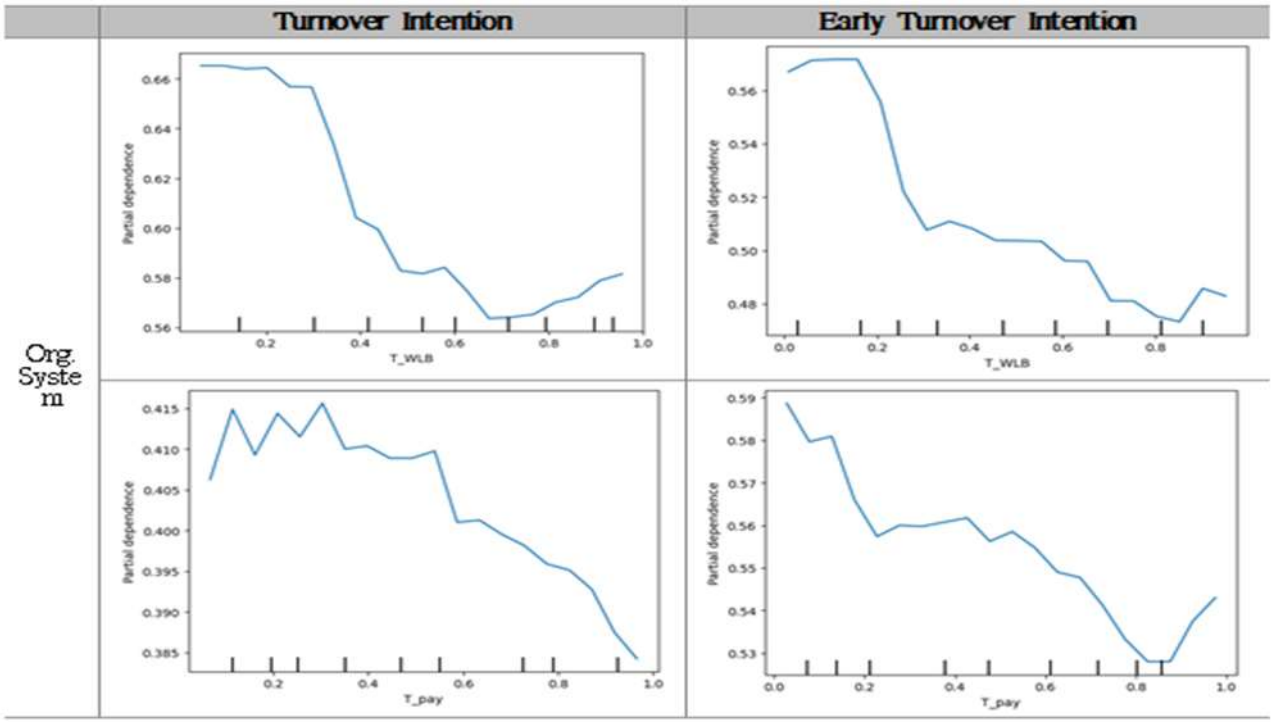

Figure 4. PDP Result-Org. System

Among the top 10 variables in the importance index, the socio-psychological factor includes satisfaction with personal development potential. As satisfaction with personal development potential increases, the intention for turnover and early turnover decreases. On the other hand, the relationship between early turnover intention among early-career individuals and the factor of personal development potential showed a steep downward curve. This can be interpreted to mean that even a slight increase in the perception of personal development potential among early-career individuals significantly impacts their turnover intention (Figure 5).

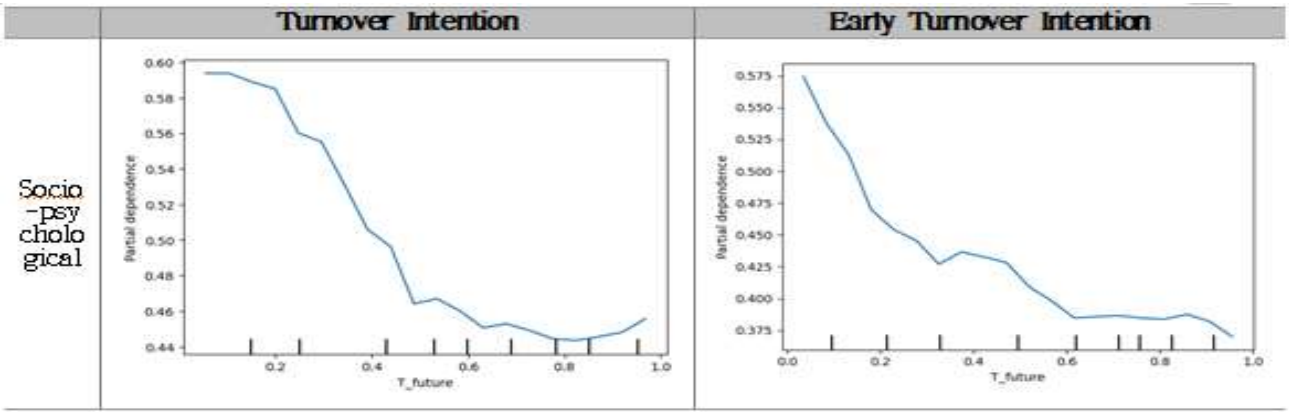

Figure 5. PDP Result-Socio Psychological

Education level, a control variable, was included among the top 10 variables in the importance index. The higher the level of education, the greater the intention for turnover and early turnover. For public officials, a higher level of education correlates with a higher turnover intention, and those who have completed graduate school, including master's and doctoral programs, show increased turnover intention. Among early-career individuals, those who graduated from a four-year college exhibit the highest tendency for early turnover intention (Figure 6).

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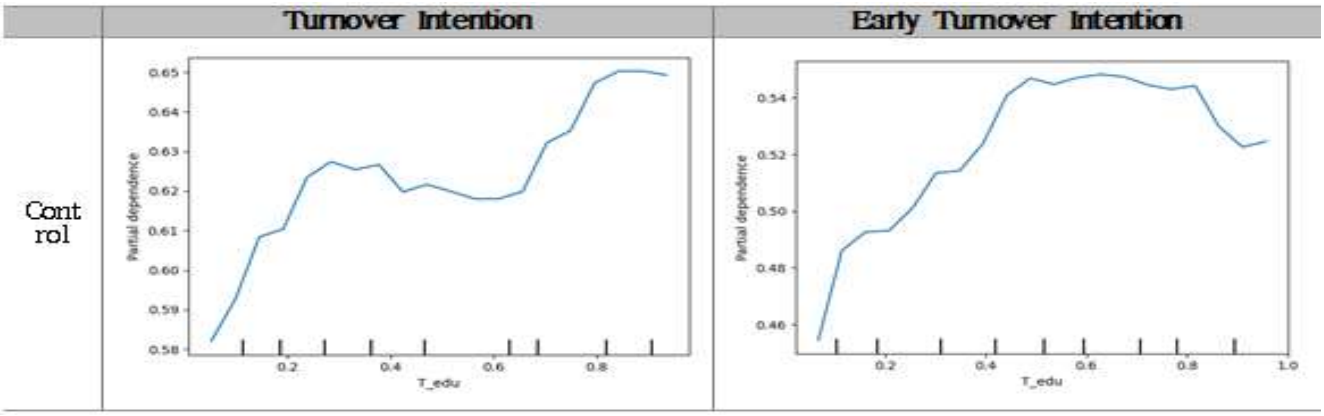

Figure 6. PDP Result-Control

CONCLUSION

This study utilized seven years of data from 2017 to 2023 from the Public Employee Perception Survey to examine the turnover intentions and early-career turnover intentions of public employees. Furthermore, the study aimed to explore the key influencing factors by selecting the method with the highest accuracy in predicting early-career turnover intentions among Random Forest, SVM, and Naive Bayes. This study has found that random forest has better prediction than other machine learning method, securing high accuracy and F1 score.

According to the result, there are no big differences between the turnover intentions and early-career turnover intentions of public employees. According to the Variable of Importance Index result, the most remarkable variables in predicting (early-career) turnover intention in the public sector are P-O fit and P-J fit, satisfaction with welfare benefits system and perception of HR fairness, job satisfaction and autonomy, and workload. It was notably found that future prospects have a greater impact on turnover intentions among early-career employees than the workload itself. In addition, regarding the PDP result, this study has provided what points and level of variables affect (early-career) turnover intention. Changes in factors affecting early-career turnover intention among individuals are much more sensitive compared to the relationship between factors influencing the turnover intention of employees and turnover intention. In other words, the marginal effect of early turnover intentions among early-career individuals is much greater than the marginal effect of turnover intentions among general public employees when the impact of predictor variables changes.

This study seeks to derive policy implications for reducing (early-career) turnover among public employees. First, after examining the partial dependence plots showing the detailed patterns of early turnover intentions among new employees and the top variables in the importance index, it was concluded that efforts related to job-related factors by the government are most needed. In particular, for P-E fit, it was found that a slight effort can significantly reduce early-career employees' turnover intentions. Additionally, it was observed that there are inflection points where the probability of early turnover drops sharply concerning job satisfaction and workload. Specifically, the probability of early turnover increases significantly when job satisfaction exceeds 40% or when employees feel that the workload is 40% higher. Government tries to check their employee's satisfaction level and over-workload level in order to reduce early-career turnover intention.

Second, according to the PDP result, the certain level of job autonomy should be ensured to reduce early-career turnover intention. Providing too little or too much autonomy can also influence early-career turnover intention. Leaders need to grant a certain level of job autonomy to early-career employees. In doing so, leaders should consider various factors such as the employees' work style, attitude towards work, and competencies when determining the level of autonomy. For example, leaders should grant a high level of job autonomy to employees with high work competencies and a positive attitude towards work, while providing a lower level of autonomy to those with lower competencies and a less favorable attitude towards work.

Third, Salary and satisfaction with welfare benefits system are crucial factors in determining turnover intentions for early-career employees. According to the PDP results, a drop-in work-life balance below approximately 20% or a

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decrease in salary satisfaction below 15% appears to significantly influence turnover intentions of early-career civil servants. Government should establish family friendly culture, providing smart work system, flextime work system, family health support programs, dependent family support programs, family leisure activity support, and so on. In addition, salary for civil servants should be restructured. of August 2024, the starting monthly salary for a Grade 9 public servant, who is early-career one, is about 25,000 dollars before taxes. This is approximately 200 dollars more than the minimum wage, based on a 40-hour workweek. Government should restructure salary system and increase early-career civil servants, reducing turnover intention.

Fourth, early-career civil servants tend to leave their job when they have high degree, such as P.h.-D. The Korean government provides financial support to public employees to pursue degree programs, enabling them to continue their service while enhancing their capabilities. Public employees who complete their studies and earn degrees, either domestically or abroad, can achieve better performance. However, it has been observed that early-career employees with a doctoral degree tend to have a higher intention to leave. Therefore, the government should actively support the pursuit of master's degrees for public employees but exercise caution regarding their pursuit of doctoral degrees.

The study has several limitations. First, employee turnover can be categorized into avoidable and unavoidable turnover, as well as planned and unplanned turnover. Most early-career turnover is considered voluntary (avoidable turnover) rather than due to contract completion, retirement, or health reasons. The data used in this study are based on turnover intentions, which means that factors such as planned vs. unplanned and avoidable vs. unavoidable turnover were not considered. Second, the study does not include an analysis of how much the analysis performance has improved compared to general logistic regression. Moreover, this study does not include different types of machine learning methods, such as K-nearest neighbours, XGBoost, Neural Network, Lasso logistics regression model, and so on. Thus, future studies need to include different type of turnover, such as voluntary and involuntary turnover with various machine learning methods.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (NRF-2023S1A5A8082038).

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