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The Factors Affecting Human Resources Productivity in Urban Construction Projects: A Comparison of Relative Importance Index and Fuzzy Logic Methods

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ABSTRACT

Human resource productivity is one of the main concerns in organizations. In total,100 factors According to on three main sources: 1- Opinions of experts and academic professors, 2- Using project technical documents, 3- Previous similar research studies and related scientific sources, were identified and categorized into four groups: plan human resource management, acquire project team, develop project team, and manage project team. Questionnaires were distributed among 103 members of the target population who were active construction contractors in Iran. The questionnaires were analyzed using two methods: Relative Importance Index (RII) and the Fuzzy Logic (FL). Ten factors that had the highest impact, based on the two methods, on HRP efficiency in the projects were identified and compared. The results of fuzzy logic and RII method showed that both methods were highly similar in terms of outcomes. In addition, the results indicated that "lack of proper communication between the technical office and workshop" was the most important factor based on the two techniques mentioned.

1. Introduction

In today's competitive world, productivity is one of the key components to ensure the success and profitability of an industry or a project [10]. Productivity can be attributed directly to the amount of cost reduction or increased profitability. The construction industry plays an important role in the economy of any country. This industry is a key part of the national economy for countries around the world [20]. The construction industry is an essential part of the community, while the productivity of the work, which represents the amount of work done per hour, is a vital element in the construction process. One of the main factors contributing to the growth of the construction industry is productivity and is mainly related to the performance

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of manpower.

Productivity is one of the most critical and effective criteria to evaluate the performance of human resources in construction projects, which can play a significant role in the success or failure of a project [42]. Nowadays, human resources are the most valuable factor in production, the most important capital in organizations and companies, and the source of competitive advantages [22]. Many factors can potentially affect the productivity of the CLP [*]workforce. CLP is a form of efficiency measuring that is mainly defined as the ratio of output units (eg, project components) to the input unit (eg, work hours and work costs) or vice versa [28]. Since construction is an efficient industry, CLP usually reduces costs and time in projects [1]. To overcome this, the construction industry is constantly trying to identify CLP improvement strategies [19]. With the start of a new project, the project team settings must change. This creates the need for new processes such as the allocation of workforce to the project. However, project managers first need a CLP model that helps them identify which factors lead to a positive CLP change and how much [48]. In addition, precise CLP forecast is essential for effective planning before and even during project implementation [4]. The workforce consumes a significant amount of costs in construction projects, so work efficiency is the determination of cost optimization [18]. The advantage of productivity is seen as a decrease in construction time and cost [14].

Given the global economic impact of the construction industry, it is also important to measure performance in construction. Therefore, effective project management is very important for higher levels of performance in construction [7]. Human resources are the main factor in the completion of the project with budget, scheduled schedule and optimal quality. One of the most effective factors in human resource management in the performance of the project is the formation of the project team. The construction industry faces challenges to implement effective human resource management because of the complexity and time nature of projects [44]. The lack of effective management activity on construction resources can potentially reduce the productivity of the work. Therefore, project managers familiarize with work efficiency factors is important [18].

2. Literature Review

The past studies that have been reviewed for this paper can be classified into three categories: (1) use of context in past CLP studies and (2) Fuzzy Logic in CLP and 3-Relative Importance Index (RII) in CLP.

2.1. Use of Context in Past CLP Studies

Hamza et al. [21] reviewed CLP in 88 scientific studies using keyword construction work efficiency. The studies were thoroughly reviewed to identify CLP-related factors and rank them according to the exact items. The importance of CLP factors was also determined according to geographical areas. The methods used to estimate CLP based on the factors were briefly discussed, and finally, the CLP improvement recommendations were made. Ghattas et al. [16] is about the impact of human resource management on project performance. A study of contract experts is working on Egyptian construction projects. The ten main factors of human resource management (goals, job descriptions, recruitment, education, communication, leadership, team relationships, people's preservation, trust and values, and ultimately evaluation and motivation) have been evaluated for their communication and impact.

One of the drawbacks of using productivity quantifying methods is that these methods are not usually applicable to all sectors of the manufacturing industry. Productivity is also important throughout the project and cannot be assessed in specific parts of the project or generalized throughout the project. In addition, as activities in construction projects are complex and interrelated, one cannot examine them separately as it might lead to certain errors. Thomas and Daily [47] used a 5 -minute evaluation technique. In this technique, the performance of each of the workforce is evaluated during the observation time, and if the time spent for each type of work is more than 50% of the total time, each individual in that particular interval is given a score. By dividing the sum of the scores given for the efficiency of individuals on the entire score, the performance of human resources is obtained.

[1]- Construction Labour Productivity.

The major drawbacks to the 5 -minute evaluation technique and the work sampling are that most of the data is collected based on the observer's mental judgment and is accompanied by error [40]. Goodarzizad, P. [17] is about intends to measure the CLP of the concrete pouring operations related to the construction of commercial-office complex projects in Iran. For this purpose, 19 critical factors with significant impact on the CLP were identified and listed in five groups, including individual, managerial, economic, technical, and environmental aspects. Then, a hybrid model based on artificial neural network (ANN) and Grasshopper optimisation algorithm (GOA) was developed to determine the most influential factors and increase the CLP model's precision. Data related to the CLP of 24 under-construction commercial-office complex projects in Iran were gathered. Results reveal the most influencing factors on the CLP are labour experience and skill and motivation of labour from the individual group, the amount of pay from the economic group, site accidents from the technical group, proper supervision from the management group, and weather conditions from the environmental group.

2.2. Fuzzy Logic in CLP

When it was introduced by Zadeh [52], fuzzy set theory transformed the way that uncertainties are modeled. Fuzzy sets extended the notion of classical (i.e., crisp) sets, and classical (i.e., Boolean) logic was therefore extended to handle fuzzy sets, leading to the new approach of fuzzy logic. Fuzzy sets were first introduced to represent the values of real-world parameters when the boundaries between different states of a parameter are not sharp (i.e., not crisp), due to the subjectivity or vagueness of the measure (e.g.,warm weather), incomplete information, or ambiguity in specifying an exact value (i.e., nonspecificity or resolutional uncertainty) [41]. Fuzzy sets and fuzzy logic provide an approach to modeling the uncertainties of real-world parameters that is complementary to probability theory, which addresses random uncertainty. Fuzzy logic enables the mathematical translation of linguistic variables into numeric form; it also allows reasoning with ambiguous information and in the absence of complete and precise data [53]. Fayek and Oduba [12] identified factors in productivity and developed fuzzy membership functions and expert rules. The validity of the models was verified using data collected from a real construction project. It is important to convince industry professionals to use fuzzy logic and expert systems modeling to help them solve real-world problems. Gerogiannis et al. [15] stated that the fuzzy approach is used to evaluate human resources and select software projects based on their skills as well as the skills required for each activity in the project. Examining the limitations of fuzzy logic and understanding how to combine this theory with other modeling techniques was used to develop fuzzy hybrid techniques and describe aspects of construction and decision problems that were effectively modeled using these techniques .

2.3. Relative Importance Index (RII) in CLP

Jarkas [26] investigated the contractors' views through a structured survey of the factors in productivity and classified them under the following major groups:(1) management ;(2) technology; (3) labor; and (4) external factors. Using the RII method, the following were the most important factors in labor productivity:(1) work skills, (2) coordination between design disciplines, (3) lack of work supervision, (4) design errors, (5) delays in responding to information requests, (6) rework, (7) careful inspection by the engineer, (8) overtime, (9) lack of incentive plan, and (10) bad weather. Vigneshwar and Shanmugapriya [49] examined the factors affecting the productivity of the construction site. A total of 28 factors under 7 groups were categorized as subgroups: labor restrictions, safety and quality, materials and equipment (ME), site management, project working conditions, delay control, construction methods and techniques and external factors. In addition, by engaging these factors, the questionnaire was conducted among Indian construction physicians. As a result, 204 answers were received and the data were analyzed using reliability test, relative importance index (RII) and analysis of variance (ANOVA). The result of this study highlights the importance of strategic construction management activities in terms of effective ME planning, realistic planning and planning of construction activities, appropriate communication, information sharing and more. Therefore, this study provides a clear insight for Indian construction physicians in determining the impact of these site factors on the successful implementation of their projects. Hiyassat et al. [23] analyzed the factors affecting the efficiency of construction work. Their questionnaire consisted of 27 questions (variables) and the efficiency was analyzed by calculating the average standard deviation and RII of each variable. They concluded that the top three factors, increased productivity as

an increase in experience increased "financial incentives to increase productivity" and "trust and communication between management and workers". Alaghbari et al., [2] distributed a questionnaire to architectural and structural engineers working on construction projects. The questionnaire consisted of 52 predefined factors categorized into four main groups: human, managerial, technical and technological labor, and external factors. The RII was determined and the factors were ranked. The results showed that the technical and technological factors were in the first place among the four groups. The top five factors that had the most important impact on labor productivity in construction in Yemen were: (1) work experience and skills, (2) availability of materials on site, (3) leadership and efficiency in site management, (4) the availability of materials in the market, and (5) the political and security situation.

Given that the previous studies have been mostly related to construction projects in general, it is necessary to adapt these factors to the existing conditions in the urban construction industry. Therefore, there is aneedto combine these complex and interdependent activities.

This study tries to answer three general questions:

1. What is the ranking of productivity indicators in the construction industry, based on Fuzzy Logic (FL)?
2. What is the ranking of productivity indicators in the construction industry, based on the Relative Importance Index (RII) method?
3. Are the results of FL method and RII method compatible with each other?

3. Research Methodology

Since productivity indices are relative numbers, whether high or low, they require a basis for comparison. Similar competing individuals and companies in similar fields are examples of benchmarks. Individual comparisons are commonly used to evaluate employees and productivity-based systems at the company level for intercompany comparisons, relative positioning, and competitive analysis. They are even used at the national level to determine countries' competitive position. If two or more individuals, companies, organizations, or countries are compared on the basis of a productivity index, the comparison will be very simple to the extent of arranging a set of numbers in an ascending or descending order. However, if the indicators and criteria of comparison are more than one, the problem becomes complicated and needs a multi-criteria decision

3.1. Target Population

An appropriate target population should be selected before distributing the questionnaires. While the selected samples need to represent the entire target population, the responses obtained should be reliable and valid. Additionally, the impact of each factor on the productivity of human resources in the workshop should be representative of the urban construction sector of a country. As such, the target population for the distribution of questionnaires was purposefully selected from the main groups active in urban construction projects. In this study, 103 questionnaires were distributed in the target population working in reputable companies and 103 questionnaires were received. That is, the target population consisted of 103 construction companies in Iran (Tehran), which increased the reliability of the findings. In fact, the study was carried out through census rather than sampling.

3.2. Questionnaire Structure

A questionnaire is needed to compare and prioritize the identified criteria highlighted by the target population. This method helps to better understand the proposed model because the results of the questionnaire are acceptable and relevant to the conditions of each company and individual. In order to design a questionnaire, appropriate resources are needed to make sure that the answers are close to reality. The respondents must determine the importance of each factor in HRP. Questionnaire items ask the respondents to evaluate the issue and only answer the relevant issues raised. Using mental judgment and past experiences, the respondents determined the importance of each factor by marking the desired alternative (not important, slightly important, important, fairly important, and very important). The questions in the questionnaire were developed based on three main sources: 1- Opinions of experts and academic professors, 2- Using project technical documents, 3- Previous similar research studies and related scientific sources. The questions contained 100 questions and it was examined by experts thoroughly and modified based on the experts' opinion. Validity of the tool was

confirmed after implementing the modifications. Reliability of the tool was examined using Cronbach's alpha. There are different approaches to categorize the factors in HRP. In this study, the factors have been taken from the subgroups of the above groups that are related to inputs, tools and techniques, and outputs. It should be noted that these groups and their subgroup factors have overlapping factors, and this is inevitable and confirms the interaction of these groups.

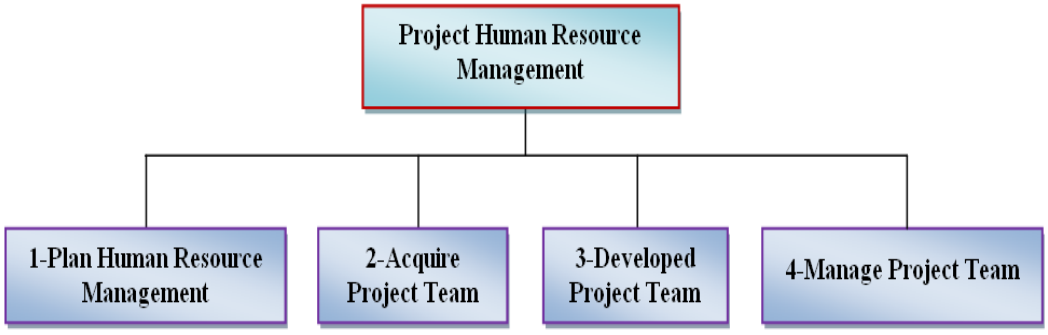

Figure 1. Grouping of factors

The questionnaire was designed based on Likert's five-point scale (Not Important, Slightly Important, Important, Fairly Important, and Very Important) with 100 questions. The number of questions related to each of the four categories is listed in Table 1. To determine the validity of the questionnaire which was conducted in the form of a survey, the opinions of professors, specialists, and experts were sought.

Table 1. Number of items related to each group of HRP factors

Group	plan HRM	acquire project team	develop project team	to manage project team	**Total items factors**
Number of items	30	13	24	33	100

Finally, the designed questionnaire (Table 2, Table 3, Table 4 and Table 5) was provided to the target population in hard copies or via email.

Table 2. The first group regarding the factors in HRP

Grouping	**Row**	**Item**	**Row**	**Item**	**Row**	**Item**
1- Plan Human resource management	1	Clarity of role	11	Distance from the population center [3]	21	Seasonal workers [3,30]
	2	Use of native labor [3]	12	Cultural conditions	22	Emergency stop
	3	Low literacy	13	Use of assignment matrix [46]	23	Identify innate talents
	4	Training forecast [46]	14	Economic conditions	24	Matching authority with responsibility
	5	Vacation [46]	15	Distance from place of residence to work	25	Use of theory and organizational chart
	6	Risk forecasting	16	Safety and health [43]	26	Holding educational courses
	7	Identify skills based on WBS	17	Competitive environment	27	welfare amenities
	8	Addiction	18	Criteria for rewards and fines [46]	28	Use of people outside the organization [43]
	9	Labor release program	19	Specified without the right to use resources	29	Geographical conditions [37]
	10	Workshop access conditions [11]	20	Historical information for similar projects [31]	30	Check resume before hiring

Table 3. The second group regarding the factors in HRP

Grouping	Row	Item	Row	Item	Row	Item
2- Acquire project team	1	Appointment of forces by pre-selection	5	Contractual understandings	9	Short-term contract
	2	Specialized meetings within the [35] organization	6	Added new forces	10	Lack of access to skilled labor due to high cost of training [46]
	3	Identify the weaknesses of the forces in the competing project	7	Companies required by the government to use skilled labor [43]	11	Project schedule [5,11]
	4	Multi-skill labor [30]	8	Save time for emergencies	12	The appointment of a negotiated force
					13	Use of IT

Table 4. The third group regarding the factors in HRP

Grouping	Row	Item	Row	Item	Row	Item
3- Develop project team	1	The role of rewards and penalties in team performance [30]	9	Performance evaluation based on pivotal result	17	Guide new forces before starting work
	2	Low level of expertise and skills	10	Excessive change of forces [30,35]	18	Improving the culture of teamwork [11,30]
	3	The role of retraining in team performance	11	Psychology of forces [32,39]	19	Personal and religious beliefs
	4	Dissatisfaction with shortages and delays in payment of salaries	12	Expect too much work in the role [3]	20	The way of treating employer, consultant and contractor [43]
	5	Success feedback based on initial goals	13	Creativity and innovation of forces	21	Geographical distribution of team members [32]
	6	Project time performance [3, 11]	14	Absenteeism, late start and early completion	22	Improve the sense of trust between team members
	7	Project budget performance [11]	15	Disciplinary measures in team performance	23	Job promotion
	8	Performance-based performance review	16	Pursue the problems of the forces through negotiation	24	Share knowledge between people with virtual teams [27]

Table 5. The fourth group regarding the factors in HRP

Grouping	Row	Item	Row	Item	Row	Item
4- Manage project team	1	Reserve force	12	Insurance of forces	23	Cost overflows
	2	Temporary or permanent work	13	Labor inspection	24	Identify personal and technical conflicts through emotional intelligence
	3	Local policies and stakeholders	14	Strike forces	25	Timely issuance of work permits
	4	Recruit new Managers [3,30]	15	Lack of proper communication between the technical office and the workshop [38]	26	Ignoring expertise when planning
	5	Irregularities in work[29]	16	Convenience of working in a state project [43]	27	Completeness of maps
	6	Deliberate failure [3,29]	17	Convenience of working in a private project	28	Control and allocation of forces
	7	Negligence in the workplace [39,43]	18	Loss of force during adjustment [36]	29	Pay attention to feedback
	8	Equipment and machinery failure	19	Rework	30	Work at night [11]
	9	Evaluation of the performance of team members	20	Interaction between employer, consultant and contractor	31	Uniqueness of work
	10	Unfamiliarity with new equipment	21	Change of foremen	32	Improper execution method
	11	Diversity of management skills [30]	22	Increase of work shifts	33	Influence of managers on team members

4. Evaluation Proposed Methods (RII method)

The RII Method was used to identify the priority of important factors and then reliability analysis was performed to check the consistency of the received data. Factor analysis is used to reduce the size of the data and identify the grouping of features based on the correlation among them [8]. One of the common methods for quantifying qualitative responses and ranking factors is the use of the Likert's scale and RII methods. As shown in Eq. (1), in each calculation, the answers related to each cause are used to calculate the percentage of respondents associated with a specific score for each cause:

$$R = \frac{\sum_{i=1}^{n} r_i}{M \times N} \quad (1)$$

Where r is the weight that the respondent gives to the desired factor, which is a number between 1-5, M is the maximum weight, which is equal to 5, and N is equal to the number of respondents. Finally, the factors are ranked based on the size of this index [45].

5. Fuzzy Logic

Fuzzy systems are one of the most important models in fuzzy set theory [9]. Fuzzy logic is one of the new methods in the theory of uncertainty. In this method, language variables can be easily and conveniently converted into numerical variables. In other words, in fuzzy logic and using fuzzy numbers, the qualitative answers of the respondents can be converted into quantitative answers and used in mathematical relations. Due to the fact that in this study the questionnaires were answered using linguistic variables (not important, slightly important, important, fairly important, and very important), fuzzy numbers were used for weighting and

quantifying the answers. The theory of fuzzy sets has been proposed to deal with uncertainties caused by inaccuracies and ambiguities. A major part of fuzzy set theory is the ability to display ambiguous data. Fuzzy set theory can be used in many areas that require the management of uncertain values such as HRP management. Fuzzy logic is used to provide conceptual expression to demonstrate knowledge and reasoning under inaccuracy and uncertainty [51]. Fuzzy systems, due to their ability to combine specialized and human knowledge, have been successful in many areas such as control, modeling, classification, data mining, computing, etc. and many studies have used fuzzy systems to address inaccuracies and uncertainties and describe the behavior of complex systems without the need for a precise mathematical model [50].

5.1. Triangular Fuzzy Numbers

A triangular fuzzy number like $\tilde{A}$ is represented as $\tilde{A} = (a^l, a^m, a^u)$where a^l, a^m, and$a^u$are called the left foot, middle foot, and right footer spectively. The membership function of$\tilde{A}$is defined as follows [25]:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a^l}{a^m-a^l} a^l \le x < a^m \\ \frac{a^u-x}{a^u-a^m} a^m \le x < a^u \\ 0 \quad \text{otherwise} \end{cases} \tag{2}$$

5.2. Fuzzy Numbers Calculus

Addition, subtraction, multiplication, and division operations for the two triangular fuzzy numbers, $\tilde{A} = (a^l, a^m, a^u)$ and $\tilde{B} = (b^l, b^m, b^u)$, and the scalar number $(k)$are as follows [24]:

$$\tilde{A} + \tilde{B} = (a^l + b^l, a^m + b^m, a^u + b^u) \tag{3}$$

$$\tilde{A} - \tilde{B} = (a^l - b^u, a^m - b^m, a^u - b^l) \tag{4}$$

$$\tilde{A} \times \tilde{B} = (min\{a^l b^l, a^l b^u, a^u b^l, a^u b^u\}, a^m b^m, max\{a^l b^l, a^l b^u, a^u b^l, a^u b^u\}) \tag{5}$$

$$\frac{\tilde{A}}{\tilde{B}} = (min\left\{\frac{a^l}{b^l}, \frac{a^l}{b^u}, \frac{a^u}{b^1}, \frac{a^u}{b^u}\right\}, \frac{a^m}{b^m}, max\left\{\frac{a^l}{b^l}, \frac{a^l}{b^u}, \frac{a^u}{b^1}, \frac{a^u}{b^u}\right\}); 0 \notin \tilde{B} \tag{6}$$

$$k \times \tilde{A} = (ka^l, ka^m, ka^u);\ k \ge 0 \tag{7}$$

Table 6 lists the conversion of five linguistic variables to triangular fuzzy numbers [34]. Based on Table 6 the answers mentioned in the questionnaires, which are linguistic variables, can be weighed and quantified. Mathematical operations can also be performed on them and the impact of each factor can be determined. For this purpose, by obtaining the mean of the weight of the answers given for each factor, the power of fuzzy number A is determined as its effect. Figure 2 illustrates the Likert spectrum of the fuzzy number.

Table 6. Criteria for converting five linguistic variables into triangular fuzzy numbers [34].

Linguistic collection	Not Important	Slightly Important	Important	Fairly Important	Very Important
Fuzzy weight	(0,0,0.2)	(0.1,0.25,0.4)	(0.3,0.5,0.7)	(0.6,0.75,0.9)	(0.8,1,1)

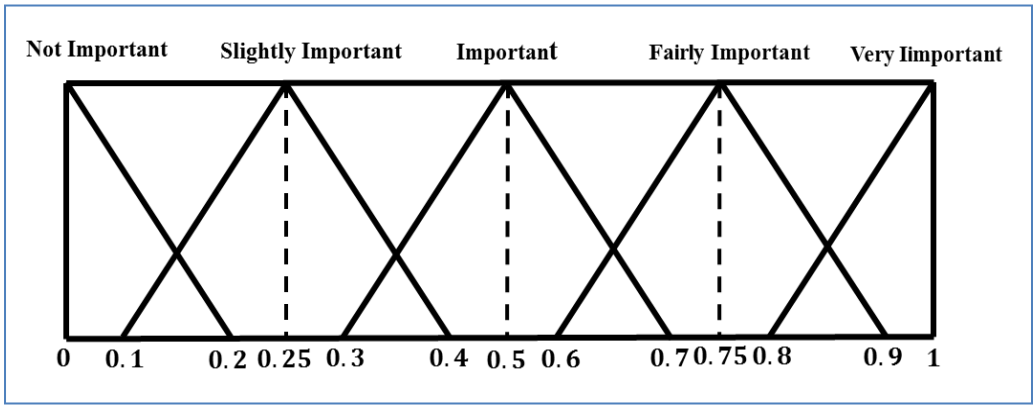

Figure 2. Likert spectrum in fuzzy mode

As shown in Eq. (2), the fuzzy number for each factor is the fuzzy weight of the answers based on the number of target population. Where A is the fuzzy number of the effect of a factor, $\tilde{k}_i$ is the fuzzy weight of responses to that factor, and n is the number of responses.

$$\tilde{A} = \frac{\sum_{i=1}^{n} \tilde{k}_i}{n} \quad (8)$$

After collecting the questionnaires, the factors of the questionnaire were quantified using the RII method and the fuzzy logic method in SPSS (version 25.0). Then, the factors in productivity were ranked and their degree of importance was determined. Given that the obtained numbers are of the triangular fuzzy type, therefore the ranking methods of this type of numbers should be used. The center of gravity or area method was also used. For fuzzy number A, the center of gravity was obtained from Eq. (9), where W_A is the equivalent fuzzy weight,(a^l, a^m, a^u) [33]:

$$W_{\tilde{A}} = \frac{a^l + a^m + a^u}{3} \quad (9)$$

Since the RII method deals with definite numbers, it is easier to use in statistical calculations. Therefore, RII method, fuzzy logic method, and center of gravity methods were used to analyze the results.

6. Results and Discussions (Description of Target Population)

The target companies in this study have valuable experiences in the construction industry. One of the ways to evaluate these experiences is a descriptive statistical study of people's work experience (Table 7).

Table 7. Comprehensive target population based on experience in each group

Experience Level(years)	Less than 5	5-10	10-15	15-20	20-25	More than 25	**Total**
Number	8	15	21	18	20	20	103
%	7.8	15.5	20.4	17.5	19.4	19.4	100

As listed in Table 7, the majority of the participants were highly experienced.

6.1. Data description

The absolute frequency of the options selected by the target population is presented in Table 8. The large number of items answered “very important”, “slightly important” and “important” reveals that the questions and factors selected in the questionnaire are of high accuracy and importance.

Table 8. Absolute frequency of options selected in the questionnaire

	Not Important	Slightly Important	Important	Fairly Important	Very Important
Number	-	6	2058	4118	4118

6.2. Results of RII

One of the methods used to analyze the results of the questionnaires and rank the factors is RII method. In Figure **3**, the factors in productivity are ranked based on RII method along the weight of the target population. The RII of 99 factors is more than 0.8 and only for one of the factors it is equal to 0.798. In addition, for 64 factors, this number is more than 0.85. This shows importance of the selected factors in the productivity of human resources in urban construction.

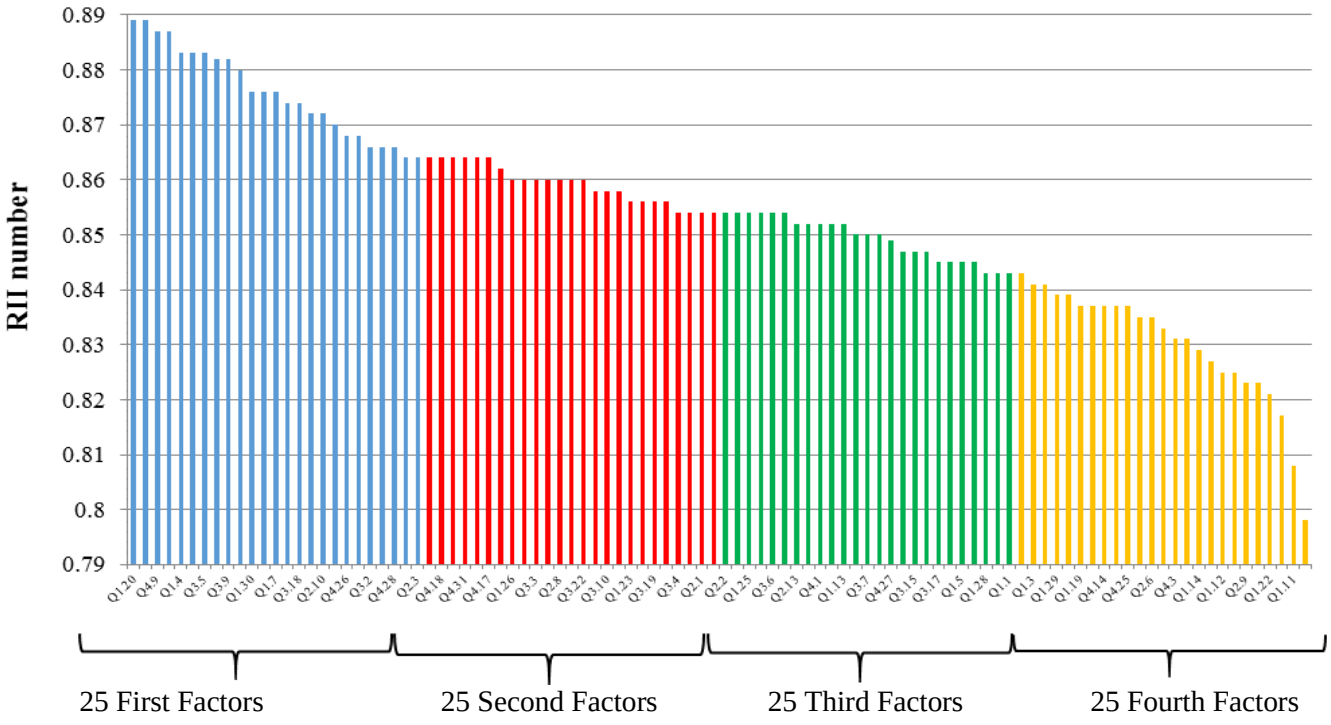

Figure 3. Analysis of 100 factors based on the RII

6.3. Results of FL

In order to better prioritize and compare the factors in the productivity of human resources in urban structures, fuzzy logic method was also used (Table 9). To better understand the results of Table 9, an analysis is presented in Table 10.

The fuzzy number of 98 factors is more than 0.75 and that of 33 factors is more than 0.8. This indicates the accuracy of the number of selected factors compared to the index method of RII. Clearly, there is a slight difference between the ranking of factors in these two methods. A closer look at the two methods reveals that RII method assigns a definite number such as 1,2,3,4, and 5 to qualitative responses, while the fuzzy logic method assigns a triangular fuzzy number (fuzzy weight), (e.g.0.1,0.25, and 0.4) and (0.3,0.5, and 0.7) (see Table 6) and attributes it to the qualitative responses that cover an interval. In the first fuzzy weight, this interval is equal to [0.1 ~ 0.4]cc and in the second phase, the weight is equal to [0.3 ~ 0.7]. The interval of these two numbers overlaps, which is due to the fact that the two numbers are uncertain. Given that the target population gave qualitative answers to the questions, it is appropriate to attribute uncertain numbers to a range. For example, when the respondent selects the average option, the response can range from slightly below the average or slightly above the average. Therefore, fuzzy number assignment can reveal the answers more accurately. The fuzzy logic model enables us to use linguistic and qualitative expressions to obtain more accurate information about the existing conditions. It also largely covers the problems caused by the overlapping conditions among factor levels.

Table 9. Comparison of all factors based on fuzzy numbers

Rank	Question code	Score	Rank	Question code	Score	Rank	Question code	Score	Rank	Question code	Score
1	Q4.15	0.831	14	Q3.20	0.812	26	Q4.22	0.805	39	Q2.8	0.798
2	Q1.20	0.829	15	Q3.2	0.811	27	Q4.18	0.804	40	Q3.14	0.798
3	Q4.9	0.826	16	Q2.10	0.810	28	Q4.33	0.804	41	Q3.19	0.797
4	Q3.5	0.823	17	Q1.30	0.809	29	Q1.16	0.803	42	Q4.1	0.797
5	Q3.9	0.823	18	Q4.4	0.809	30	Q2.3	0.802	43	Q2.11	0.796
6	Q4.30	0.823	19	Q4.28	0.809	31	Q2.7	0.802	44	Q3.8	0.796
7	Q1.4	0.822	20	Q4.31	0.809	32	Q4.16	0.802	45	Q3.10	0.796
8	Q4.20	0.821	21	Q3.16	0.808	33	Q4.17	0.802	46	Q4.5	0.795
9	Q4.32	0.818	22	Q4.26	0.808	34	Q1.26	0.799	47	Q4.13	0.795
10	Q2.4	0.816	23	Q3.24	0.807	35	Q3.3	0.799	48	Q1.13	0.794
11	Q4.24	0.815	21	Q4.6	0.807	36	Q3.22	0.799	49	Q1.25	0.794
12	Q1.7	0.814	25	Q3.12	0.805	37	Q4.23	0.799	50	Q2.13	0.794
13	Q3.18	0.812				38	Q1.23	0.798			
51	Q3.11	0.794	64	Q1.5	0.787	76	Q1.28	0.779	89	Q1.21	0.767
52	Q2.1	0.793	65	Q4.27	0.787	77	Q1.19	0.777	90	Q4.3	0.767
53	Q2.5	0.793	66	Q3.21	0.786	78	Q1.24	0.777	91	Q2.9	0.766
54	Q3.6	0.793	67	Q2.12	0.785	79	Q4.10	0.777	92	Q1.14	0.763
55	Q4.12	0.793	68	Q1.15	0.784	80	Q1.1	0.776	93	Q1.8	0.762
56	Q3.13	0.792	69	Q3.15	0.784	81	Q1.27	0.776	94	Q1.9	0.761
57	Q4.11	0.792	70	Q4.2	0.784	82	Q1.29	0.774	95	Q1.17	0.761
58	Q1.6	0.791	71	Q4.21	0.784	83	Q2.6	0.774	96	Q1.12	0.758
59	Q3.1	0.791	72	Q3.17	0.781	84	Q1.3	0.773	97	Q1.22	0.756
60	Q4.7	0.791	73	Q4.14	0.781	85	Q4.25	0.773	96	Q1.10	0.752
61	Q3.7	0.790	74	Q4.29	0.780	86	Q3.23	0.772	99	Q1.11	0.739
62	Q2.2	0.788	75	Q1.2	0.779	87	Q1.18	0.771	100	Q4.19	0.733
63	Q3.4	0.788				88	Q4.8	0.770			

Table 10. Analysis of 100 factors based on fuzzy numbers

	25 first factor				25 second factor				25 third factor				25 fourth factor			
Group	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Number of factors	4	2	8	11	5	5	6	9	4	4	9	8	17	2	1	5
Max	0.831				0.805				0.794				0.779			
Min	0.805				0.794				0.779				0.733			
Avg	0.815				0.798				0.787				0.766			

6.4. Cronbach's alpha

There are many methods to determine the reliability of questionnaires; however, considering the use of the Likert scale to weight the answers, the appropriate method for determining the reliability of this questionnaire is Cronbach's alpha. Eq. (10) can be used to determine Cronbach's alpha [6].

$$\alpha = \frac{k \times \overline{C}}{\overline{V} + (k-1) \times \overline{C}} \tag{10}$$

Where, k is the number of questions, $\overline{C}$ is the mean covariance of the questions, and $\overline{V}$ is the mean variance of the questions. Obviously, the closer Cronbach's alpha index is to 1, the greater the internal correlation among the questions. Cronbach suggested a reliability coefficient of 45% as low, 75% as moderate and acceptable, and 95% as high. Cronbach's alpha was obtained equal to 89.2%, which indicates that the internal correlation among the questions and the results of the questionnaires is homogeneous. This shows that the overall reliability of the questionnaires is high.

In addition, the respondents were asked to express their personal opinions about the questions of each group based on Likert's five-point scale. The results of fuzzy logic and RII methods are specified separately in Figure 4.

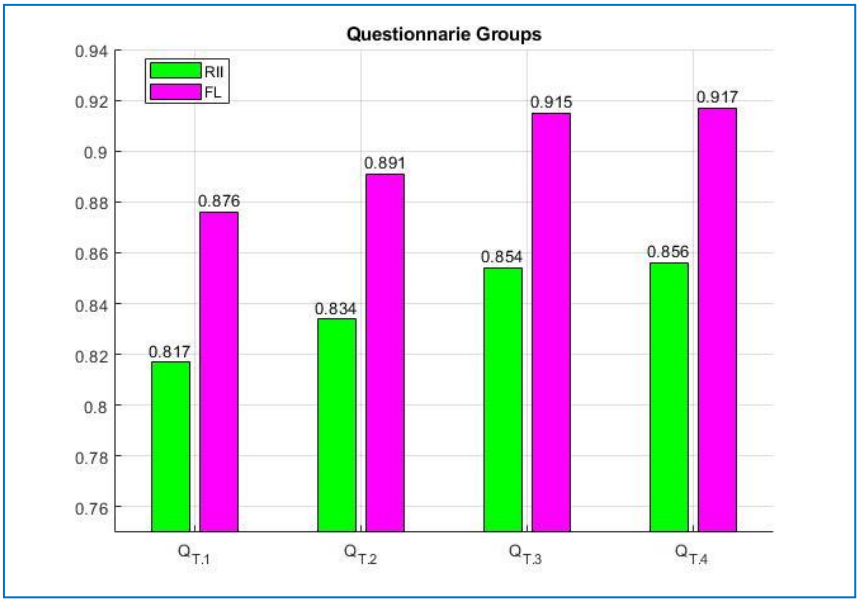

Figure 4. Analysis of general questions from the perspective of the target population as a whole

After calculating and analyzing the data, in each of the 4 main categories of questions, 10 factors with the highest fuzzy number and RII were extracted, which are listed in Table 11.

Table 11. Analysis of the top 10 factors based on fuzzy number and RII

Fuzzy Logic						RII					
Rank	Question code	Score	Rank	Question code	Score	Rank	Question code	RII number	Rank	Question code	RII number
1	Q1.20	0.829	1	Q2.4	0.816	1	Q1.20	0.889	1	Q2.4	0.880
2	Q1.4	0.822	2	Q2.10	0.810	2	Q1.4	0.883	2	Q2.10	0.872
3	Q1.7	0.814	3	Q2.3	0.802	3	Q1.30	0.876	3	Q2.3	0.864
4	Q1.30	0.809	4	Q2.7	0.802	4	Q1.7	0.876	4	Q2.8	0.858
5	Q1.16	0.803	5	Q2.8	0.798	5	Q1.16	0864	5	Q2.11	0.854
6	Q1.26	0.799	6	Q2.11	0.796	6	Q1.26	0.860	6	Q2.7	0.856
7	Q1.23	0.798	7	Q2.13	0.794	7	Q1.23	0.856	7	Q2.1	0.854
8	Q1.13	0.794	8	Q2.1	0.793	8	Q1.25	0.854	8	Q2.2	0.854
9	Q1.25	0.794	9	Q2.5	0.793	9	Q1.13	0.852	9	Q2.5	0.854
10	Q1.6	0.791	10	Q2.2	0.788	10	Q1.6	0.85	10	Q2.13	0.852
1	Q3.5	0.823	1	Q4.15	0.831	1	Q3.5	0.883	1	Q4.15	0.889
2	Q3.9	0.823	2	Q4.9	0.826	2	Q3.9	0.882	2	Q4.30	0.887
3	Q3.20	0.812	3	Q4.30	0.823	3	Q3.20	0.876	3	Q4.9	0.887
4	Q3.18	0.812	4	Q4.20	0.821	4	Q3.18	0.874	4	Q4.20	0.883
5	Q3.2	0.811	5	Q4.32	0.818	5	Q3.12	0.870	5	Q4.32	0.882
6	Q3.16	0.808	6	Q4.24	0.815	6	Q3.16	0.868	6	Q4.24	0.874
7	Q3.24	0.807	7	Q4.4	0.809	7	Q3.2	0.866	7	Q4.4	0.872
8	Q3.12	0.805	8	Q4.28	0.809	8	Q3.24	0.864	8	Q4.26	0.868
9	Q3.3	0.799	9	Q4.31	0.809	9	Q3.11	0.86	9	Q4.6	0.866
10	Q3.22	0.799	10	Q4.26	0.808	10	Q3.3	0.86	10	Q4.28	0.866

6.5. Spearman rank correlation coefficient

The Spearman correlation coefficient indicates the level of agreement on ranking among the target population, as calculated in Eq. (11):

$$\rho = 1 - \frac{6\times\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \qquad (11)$$

where ρ is the level of consensus among each pair of groups (correlation coefficient) ($-1 \leq \rho \leq +1$), d is the difference between two ranks assigned to a factor by each of the two samples, and n is the number of factors [13]. The Spearman rank correlation coefficient (ρ= 0.987) supports a high correlation between the two results of the two methods. Although both methods are different, the results are very close. It shows that the target population is aware of the general state of productivity in the construction industry. The findings can provide accurate preliminary information for future studies.

7. Conclusion

Factor Analysis of the top five factor of each group

1) Important Factors of Plan Human resource management

1-Using historical information (experiences and documentation) past work in similar projects.

One of the parts of the Human Resources Management Program is employee management, which describes the project team members when and how we need and how long we need them. The agent of the use of historical information is below the employee management program, the matching. The program has strategies to adapt to the historical information of past projects. So that project officials can identify their positive and negative points by studying previous experiences and documentation, until they have proper planning for managing their human resources.

2- Predicting training programs to achieve the necessary certificates for project development.

As mentioned, one of the parts of the HRM program is employee management that describes the project team members when and how we need and how long we need them. If the project team is not expected to have the necessary qualifications, an educational program can be developed as part of the project's human resource

management planning. The program may also have the necessary ways to help team members achieve some certificates (which are useful for the project).

3- Identify the skills and capabilities required based on the work failure structure (WBS)

(Division of project work into smaller and more management components and activities).

The roles and responsibilities are of great importance in the Human Resources Management Program. When listing these roles and responsibilities to complete the project, the competencies of individuals should be carefully considered. It is better to plan the skills and the need for human resources when planning for the failure of the work failure, rather than the financial and time resources.

4- Investigating the resume of previous forces.

In the human resource management and staff management sector, employees are very important. For example, can human resources be supplied from within the organization or from the outside or in other ways? However, the point is that any human resources are provided, the resume of the individual should be examined and the person is attracted to the project after identifying the ability in the project.

5- Safety and health of the workplace in the workplace.

In the staff management program, safety is also important. Policies and procedures that make project members safe from dangers can be included in the employee management program along with the risk registrar. Construction projects in any kind always have risks to their essence, so the risks can be reduced by observing safety and risks.

2) Important factors for the Acquire project team

1- Hiring a multi-skill workforce.

Multi -skills workforce has a special place in the formation of the project team. Because most companies prefer to attract fewer people to avoid spending money on hiring multiple people, they have the same number of more specialties.

2- Lack of skilled labor due to the high cost of training courses.

The project team updates should also be taken into account due to the high cost of training courses, as the lack of skilled workforce in projects reduces productivity. On the other hand, in order to offset this defect among human resources, training courses must always be held, which always cost a lot.

3- Identifying the strengths and weaknesses of the appointment of forces in similar competitors' projects.

In the appointment section of the forces, the experiences that take place in similar projects should always be taken care of. By examining these appointments, their strengths and weaknesses should be taken into consideration and their work process and process should Modeling.

4- Required and lack of support from companies and organizations by government agencies to use skilled workers.

In the project update section, the use of skilled workers should be required by the government for companies and organizations. This requirement can, with the adoption of laws and regulations, support companies and organizations, as well as workers and labor, which witnesses the quality of urban construction and the increase in human resource productivity. To be, the result is an increase in the useful life of buildings, which is much lower in Iran than world standards.

5- Scheduling reserved for caution.

In the resource calendar section, it documents the time each member of the project team works. Creating a reliable timetable to help people and scheduling restrictions help the project. In designing this table, it is best to consider times for precautionary people to use it as stored and stored when necessary.

3) Important Factors of Develop project team

1- The amount of feedback and technical success based on predetermined goals.

In the team performance assessment sector, by implementing the project team development efforts based on the initial goals, the feedback of success and its impact on the development of the project team can be achieved. If the goals and scope of the project are defined as defining the resources of the project, even good ideas can lead to bad results. Unknown goals are interpreted in different ways. In such a case, one cannot expect the

boundary between success and failure. The source of many dissatisfaction is to be transparent in defining goals. The exact definition of goals also expresses the scope of the work. The project range is the area of achieving goals in which the use of resources is specified at a given time and to achieve the quality of the person.

2- Performance review based on central result.

Basically, in teamwork and teamwork, the result of the whole team is the result of the criterion, not the results of the person's task. So considering the result of the whole team that originates from the results and performance of each member, the project team's development can be examined.

3- How to deal with the contractor and employer agents with the forces.

In the field of environmental updates, it is important to deal with each other. If these encounters are exceeding normal, it will cause a problem in the project environment that ultimately causes an adverse effect on human resources and reduces efficacy.

4- Improving teamwork culture.

The formation of a good project team begins with the selection of people by the project manager. In choosing individuals, especially in construction projects, their intelligence and power and speed of learning should be given more experience. People have to be able to work in the team and get a good place in the team. They must only realize the work, not personal conflicts while working. People should be able to pursue work during the time of implementation of the project. That is why the project manager should know the necessary solutions to increase the motivation of his project team members. In the area of updating the environmental factors, the team members of this culture and attitudes must be created that achieve the goals of the project through coordination and empathy in teamwork. If the team of teamwork is not prevalent, if the strongest projects and management prevails, the results will not be achieved. A group of well -organized, well -organized and well -organized people require the success of the project.

5- Low expertise and skill of the workforce. Many factors can be involved in this case, including literacy levels, work -related education, non -use of training courses, or costs. All of these factors can affect human resource productivity and make the project positive or negative.

4) Important Factors of Manage project team

1- Lack of proper communication between the technical office and the workshop.

- In the case of this factor, introducing the points involved in this can be better justified:
- Project management weakness in proper communication management for transparency.
- Description of the tasks and responsibilities of different working groups.
- Disability of the experience and expertise of the executive groups with the technical office personnel.
- Disability among two groups, as the executives of the workshop are generally operational and workers' body, but the technical office personnel consist of experts and engineers.
- The practical lack of practical confidence in the technical office personnel.
- The practical lack of technical office to the Executive Group.

As a solution can:

- Use managers with a qualification that is familiar with the principles of project management or the training of managers to enhance their knowledge.
- Applying forces with executive experience in the technical office.
- More time in the workshop, along with the executive forces, to gain greater understanding and interaction between the two groups.

2- Evaluation of team members' performance.

This factor has been taken into consideration in the process of processing process capital. Evaluation for team members can be done in a variety of ways, including sampling the tasks, reviewing the work efficiency, asking for other team members.

3- Lack of proper project planning and control.

Project planning predicts factors such as the type of activity, volume and size of activity, the duration of running, consumer resources, etc. for activities, and project control, if necessary.

Also project planning, the motivation needed to achieve the goals set in employees

The relevant creates and the project control is used if the goals are achieved to encourage them.

4- Constructive and reciprocal interaction of the employer, consultant and contractor.

All three main pillars related to a construction project must interact with each other. This interaction can be in a variety of ways, including:

- In -person meetings as pre -planned regular sessions.
- Holding meetings with representatives of these three pillars.
- Interaction in the form of office or telephone correspondence.

5- Inappropriate execution method.

The proposal is the procedure of inappropriate implementation by the contractors due to their technical weakness and the lack of technical and executive experts in the project, or may even be due to design errors or executive errors and monitoring their implementation.

Recognizing the important factors in productivity from both negative and positive aspects can be used to prepare a strategy to reduce inefficiency and effectively improve project performance. Conventional methods of identifying and categorizing HRP factors cannot consider all of these factors, so the accuracy of the results obtained from them is questionable. The most important advantage and innovation presented in this study is the reduction of the influence of individual personal opinions in the selection of the factors in the productivity of human resources. The results also showed that construction projects, especially in the urban construction industry and in the implementation phase, are highly dependent on management methods and the identification of factors with high productivity in human resources. In this study, the results of the questionnaires were analyzed using relative importance index and fuzzy number. The identified factors were ranked and compared and the 10 factors that had the greatest impact on human resource productivity in urban construction projects were very similar to the results of other studies reviewed in the literature. The results of fuzzy logic and RII method showed that both methods are highly similar in terms of outcomes and both methods have high reliability. The results also indicated that the most important fact in "plan human resource management group" was historical information for similar projects. In "acquiring project team groups" the most important factor was multi-skill labor. In addition, in "Developed project team" and "manage project team groups," the most important factors were successful feedback based on initial goals and lack of proper communication between the technical office and workshop respectively. The future studies can use methods like gray decision-making methods to rank the factors mentioned and compare the findings with similar studies like the present one.

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