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ASSESSMENT FACTORS AFFECTING THE PRODUCTIVITY OF GARMENT SEWING SECTION: THROUGH AN INTEGRATED APPROACH OF FUZZY AHP AND TOPSIS

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A B S T R A C T

The objective of the study is to the evaluation of factors affecting the productivity of garment manufacturing industries through a combination of the Fuzzy AHP-Fuzzy TOPSIS method..
five alternative systems and eight Criteria, within a specific product context with a structured questionnaire to the random selected industry, collected quantitative data about the alternative and the criteria and the products manufactured on the systems, and the analysis is done through micro soft excel solver and Visual PROMETHEE software.
In this study, a two-phased research method has been projected to find out some governing factors affecting productivity under un-certainty conditions, in particular to FAHP. It has been used for evaluating criteria weights and ranking the criteria. Among the eight criteria, low inventory level control and work in progress are the most important factor.
In FAHP and FTOPSIS for selection of the best practices of the production system, is the first one the modular production system and the second one is the unit production system. The normalized weights of the alternative production system are MPS (0.2558), UBS (0.2152), MTS (0.1962), PBS (0.1772), and SLS (0.1558).

1. INTRODUCTION

The overall goal of the industrial development strategy is to bring structural change to the economy in the world. The government of Ethiopia has given due attention to the manufacturing sector to join the international market on a large scale through developing various industrial development programs (Tesfaye et al., 2014; MOI, 2017; Adungaet al., 2016). To diversify the economy, the government has prioritized the textile and garment industry as a strategic sector (Theuws & Overeem, 2019; Manaye, 2019). Especially, garment enterprises make a significant contribution to many national economic developments of the countries and have a large potential for creating employment opportunities (Tesfaye et al., 2016; Mulugeta, 2021).

However, the production and export performance of the garment and textile industries of Ethiopia is very low; many factors influence the competitiveness of an economy on domestic and international markets. The major stumbling block for global competitiveness is the low productivity performances of the sectors (Kitaw et al., 2010; Yemane et al., 2020).

According to Ethiopia’s Textile Industry Development Institute (ETIDI) has predicted $1 billion in yearly revenue from textile and garment export during the second phase of the growth and transformation plan (GTPII). Textile and Garment industries' export

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performance during 2007/08 GC up to 2011/12 GC (2000 EFY to 2004 EFY) was 199.1 Million USD which was 49.3% of the plan. The actual export obtained during these periods ranged from 14.6 million USD to 84.6 million USD per annual (ETIDI, 2018).

Depending on the national planning and development commission of Ethiopia report on December 18/2018 the performance of the textile and garment industry in the 2016/17 fiscal year export target was 270.5 million dollars but the actual earning is 89.3 million dollars, on average around 33.02% and annual export sales growth (on average negative 1.3%) and export sales to plan ratio (on average 34.5%) (Woldehana, 2018) because of the sectors are constrained by several constraints and factors (Balchin & Calabrese, 2019; Bongomin et al., 2020). In every production-related company, productivity improvement is a prime objective. It's requiring designing and successfully implementing sound programs. Global competitiveness has forced businesses to examine their operation to make process improvements, performance evaluation of the criteria affecting productivity is needed to improve productivity and strengthen the management of the organization (Halder & Karmaker, 2018). One of the major features within the garment production environment is the production system.

Most of the garment industries in Ethiopia practice traditional production systems (Manaye, 2019; Lebi & Singh, 2018). On other hand, in the current garment market, there are tremendous different types of products, the corresponding demand for each type of product is volatile and unpredictable, and the life cycle of the products is very short, consequently, the garment retailers require their suppliers to replenish the products quickly with the exact amount they want, the traditional garment production system is very time-consuming, does not provide flexibility the change order quickly, and generates a high amount of WIP (Sarache et al., 2004; Wang et al., 2014; Sudarshan & Rao, 2013; Sudarshan & Rao, 2014; Balchin & Calabrese, 2019; Bongomin et al., 2020). Several factors are affecting the production system's performance. Thus, to solve the above problem and to reveal that, the garment manufacturers need to identify the key factors responsible for the company's productivity improvement; and implement more flexible production systems.

Evaluation of the criteria factors affecting the productivity of the organization; and selection of the best practices types of the production system is one of the crucial factors for decision-makers and practitioners in a competitive environment; and multi-criteria decision-making tools are used to rank performance and prioritize improvement action (Alkhamis, 2019). Among the multi-criteria decision-making processes, the most commonly used methods are, Analytical Hierarchy Process (AHP) and Fuzzy Analytical Hierarchy Process (FAHP), TOPSIS (Halder & Karmaker, 2018).

The selection of the most applicable MCDM tool depends on the nature and characteristics of the decision problem. Analytical hierarchy process (AHP) and data envelopment analysis (DEA) are methods that have been widely used to assess and rank multi-objective decision alternatives for integrated qualitative and quantitative approaches with desirable and undesirable variables (Anvari et al., 2014). But a recent trend is toward applying fuzzy sets, taking into account the uncertainties (Kusumawardani & Agintiara, 2015).

The aim of this study is to the evaluation of factors affecting the productivity of garment manufacturing industries through a combination of the Fuzzy AHP-Fuzzy TOPSIS method, to get the benefit of human thinking; and to compare the idea with criteria, for evaluation and selection of the best practices of the production system in the garment manufacturing industry.

It is done depending on five alternative Garment Production Systems and eight Criteria, within a specific product context with a structured questionnaire to the random selected local and foreign garment manufacturers, collected quantitative data about the alternative and the criteria and the products manufactured on the systems, and the analysis is done through micro soft excel solver.

2. LITERATURE REVIEW

2.1. Types of Garment Industry Production System

Now a day's garment companies are facing great challenges of market competition when the production systems have a problem. It is difficult to overcome the competition scenario to minimize production cost and maximize the quality of the product for customer needs. One of the major features within the garment production environment is the production system (Moin et al., 2013; Bai & Zhang, 2011; Kincade et al., 2013; Lebi & Singh, 2018).

Garment production systems are a combination of production processes, machine layout, materials handling, personnel and equipment that direct workflow and produce finished garments. Production of the garment can be increased either by decreasing input or keeping the input the same and productivity improvement is defined as the improvement of the production time and reduction of the wastage (Ramesh Babu, 2011; Singh & Singh, 2015; Lebi & Singh, 2018). Among the different types of the garment production system, some of them are listed below: sources (Moin et al., 2013; Bai & Zhang, 2011; Kincade et al., 2013; Lebi & Singh, 2018).

Most of the garment industries in Ethiopia practice a progressive bundle production system (PBS). (Manaye, 2019; and Lebi & Singh, 2018). It is one of the traditional production systems. In PBS, each operation is done by a single worker who operates a stationary machine. The worker receives the unfinished garments in bundles; then they perform a single operation on each garment. The garments then move to the next worker for the next operation in bundles. The main philosophy behind PBS is maximizing the utilization of each worker's working capacity. Due to the different and uncertain operating time needed for different operations in the given assembly task. PBS has to depend heavily on the buffers between operations to avoid the starvation of garments at some operations. Thus, in PBS, the throughput time (from the cutting pieces to finished garments) is long, and work in process (WIP) inventory is high (Wang et al., 2014; Sudarshan & Rao, 2014; Balchin & Calabrese, 2019; Bongomin, et al., 2020).

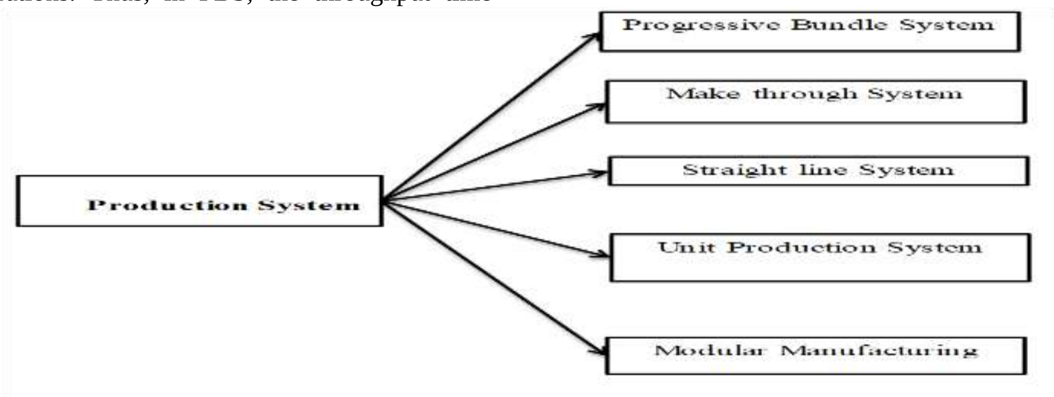


Figure 1. Types of a garment production system

High WIP is a big concern for the garment manufacturers in Ethiopia and the primary goals of a manufacturing system are to minimize the WIP inventory and maximize output rate (Haleh et al., 2014; and Roser et al., 2015). Because approximately 60% -70% of wastes occur in the garment industry due to WIP inventory and unbalanced production schedule between the cutting and sewing departments (Ahmed & Chowdhury, 2018). WIP level control is significant which delivers many advantages in the garment production system and reduction in WIP level will increase the profit by 20-25 % from the existing level (Kumar & Sampath, 2012). Therefore evaluation of factors affecting and selection of the best practices types of the production system is one of the crucial factors for decision-makers and practitioners in a competitive environment and performance evaluation of the criteria affecting the productivity of the organization (Figure 1).

2.2. Factors Affecting Productivity

Several factors can influence productivity in the garment industry. In general factors, influence production performances and productivity can be classified broadly into two categories: (A) controllable (or internal) factors and (B) un-controllable (or external) factors. However, there are multidimensional productivity factors related to human, machine, material, method, process, and organizational factors. And identifying the possible productivity factors is one of the basic elements for productivity improvement. Productivity factors can either boost or hinder productivity (Obeidat et al., 2014; Prabir & Manoj, 2018; Bappy et al., 2019; Mulugeta, 2020). In order- to solve the causes of WIP for the Bottlenecks Operation, different variables cause WIP accumulated at different production stations. The impact of WIP is to decrease productivity. The figure 2 shows the different causes of the WIP problem, the performance measure of the problem, and the outcome of the problem on productivity.

This research work will be done through identification and analyzing the critical factors affecting production system, evaluation, and selection of new practice production system, suggest productivity improvement mechanism; and work in process controlling mechanism for the new production system.

Generally the research is passing through in the following steps:

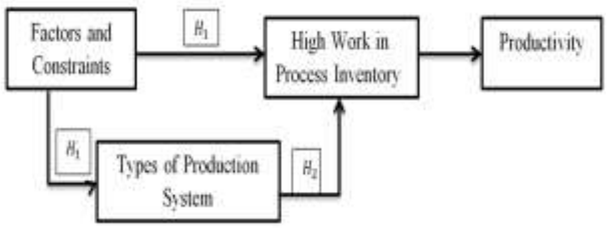


Figure 2. Conceptual Framework

Sources Company observation and literature review: (Kitaw et al., 2010; Morshed & Palash, 2014; Ferdous & Kabir, 2015;. Jameel, 2015; Wickramasekara & Perera, 2016; Bappy et al., 2019; Bayeh, 2019; Kang & Ju, 2019; Haque et al., 2018, Li et al., 2019; Manaye, 2019; Sime et al., 2019; Yemane et al., 2020).

2.3. Evaluation Criteria in Garment Production System

The choice of the best garment production system is depending on the product and policies of the company and the capacities of manpower (Islam, 2014). Different literature identifies the evaluation criteria for garment production systems depending on the competitive advantage and disadvantages of the production system, depending on the such as WIP, Through-put time, balancing the line, transportation, space utilization, quality control, manufacturing flexibility, labor skill are some of the common evaluation criteria of the production system (Table 1).

Table 1. Garment Production System Selection Criteria

No's	Criteria	Description
1	Work in Progress (WIP) level	Inline inventory between operation level,
2	Through-put time	The number of pieces that leave per time unit.
3	Balancing the line	
4	Inventory level	Fabric cutting storage needs, planning needs between operation departments, the flow of material established in between cutting and sewing line
5	Transportation	Method of retrieval to workstations, Brought to an operator from operator by cart or conveyor
6	Space Utilization	use of the plant floor,
7	Quality Control	Discover any quality problem, easier and early detection of errors, implant self-controlled systems
8	Products flexibility	(Style changes frequency) or React more quickly in front of demand changes)
9	Labor skill	capacities of manpower
10	Random change criteria	Absenteeism, machine breakdowns,

2.4. Multi-Criteria Decision Making (MCDM) tools

The knowledge about different production systems will enable a production manager to adopt and organize different production systems to improve production performances and for critical market success (Das et al., 2018). Managers need a systematic and comprehensive approach that will provide more effective decision support when any decision problems arise. Multiple criteria decision making (MCDM) is an important part of modern decision science, aimed at supporting decision-makers faced with multiple decision criteria and multiple decision alternatives. It refers to the screening, prioritizing, and ranking or selecting the best alternative from all of the feasibility alternatives while these alternatives are evaluated according to several criteria or attributes. MCDM tools are used to assist in making rational judgments when it comes to complex problems with multi-criteria and multi alternatives.

The selection of the most applicable MCDM tool depends on the nature and characteristics of the decision problem (Alkhamis, 2019). In the literature, exist several multi-criteria decision making (MCDM) methods, the developed decision-making models are based on a particular technique or algorithm which supports decision making to rank performance and prioritize improvement actions, among them, the most commonly used methods are as analytical hierarchy process (AHP), analytic network process (ANP), data envelopment analysis (DEA), fuzzy analytical hierarchy process (FAHP), grey relational analysis (GRA), decision making trial and evaluation laboratory (DEMATEL), preference ranking organization method for enrichment evaluate (PROMETHEE), (ELECTRE), and technique for order preference by similarity to ideal solution (TOPSIS) (Davim, 2015; Kusumawardani & Agintiara, 2015; Esmaili-dooki et al., 2017; Halder, et al., 2018).

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty in the 1970s. It provides a flexible and easily understandable way to analyze and decompose a decision problem, in its general form; it is a framework for performing both deductive and inductive thinking. AHP in essence is a procedure for measuring priorities in a hierarchical goal structure. It requires making pairwise comparison judgments about the criteria to derive their relative importance to the goal and pairwise comparison judgments of the alternatives concerning the criteria for preference. These judgments can be expressed verbally, and enable the decision-maker to incorporate subjective experience and knowledge intuitively and naturally. It is the most common multi-criteria decision-making method but it cannot reflect the human thinking style, Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems (Biswas, et al., 2018). Fuzzy Analytical Hierarchy Process (AHP), a set of criteria is produced and methodically weighted according to their importance. The selection is measured based on these criteria and receives a final score which reflects this importance weighting, another method that is also popular is the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In this method, the characteristics of the selected are compared to that of an ideal under un-certainty conditions, this mimics a common thought process in humans, in which people evaluate things not based on some criteria, but in comparison with an ideal instance of the same type (Ort et al., 2021). ANP deals with the interdependences between criteria and alternatives, it is recommended to be used to justify decisions and define relations between various elements in a complex system with multi factors and high interdependences (Alkhamis, 2019), associated with the subjectivity and uncertainty which is lost by forcing the decision-maker into a numeric scale. Therefore, proposed to use Fuzzy logic to express preferences in linguistic terms (Halder et al., 2018).

The AHP method is one of the most frequently applied; the total number of papers involving the use of the AHP method was 35.19%. In addition, it appears that AHP, as well as other methods, can be synthesized with other MCDM methods (Stojčić et al., 2019). Therefore, this paper applies a combination of both: the Fuzzy AHP-Fuzzy TOPSIS method, to get the benefit of human thinking and to compare the idea with criteria of selection, and to force the decision-maker into a numeric scale. In the assessment procedure, MCDM method (FAHP) has been applied to calculate the weights of the criteria and to determine crucial criteria or factor that has a strong effect on productivity improvement of garment manufacturing industries and to suggested alternative production system among the alternative use integration of Fuzzy AHP-Fuzzy TOPSIS method.

3. RESEARCH METHODOLOGY

The primary and secondary data were collected from the different sources through the different techniques integrated and presented descriptively as per the objective of the study and then analyzed and suggested alternative solutions. To complete the study, different garment manufacturing industries have been visited. Numbers of criteria have

been found that affect productivity in garments. The study has been done by taking into consideration the most frequently used eight criteria collected from reviewing literature and opinions from garment industrial Engineers, production managers, and experts in relevant fields. A set of questionnaires were completed; experts' views were integrated by using the group decision process and questionnaire.

Multi-criteria decision-making methods the integration of Fuzzy AHP and Fuzzy TOPSIS are selected. At the first stage, Fuzzy AHP is used to weigh the relative importance of criteria when compared to each other. These weighted criteria are used to assign a score to each factor in every evaluation criteria. Then this stage is followed by the Fuzzy TOPSIS, in which based on the scores that have been assigned, the proximity score of each factor to the ideal of the alternative production system, both for the positive ideal and the negative ideal. Therefore, a group decision has been conducted to improve the pairwise comparison in the evaluation process. To measure the weights of criteria by the FAHP-FTOPSIS method, pairwise comparison matrix, an input of the method has been developed. To solve the mathematical expression and draw the figure using an MS-Excel solver, a concise step of the Fuzzy AHP-TOPSIS is as follows.

3.1. Weights criteria for Selection of Production System

Evaluation of factors affecting the productivity through Fuzz-AHP: - The evaluation process consists of the following main steps according to (Alkhamis, 2019; Dolan, 2008; Atanasova-Pacemska et al., 2014; Rezaei, 2015)

- First step: - define the problem or develop a model. Identification of the evaluation criteria considered as the most important performance parameters for the RMG industry in Ethiopia
- Second step: - create a comparison matrix
- Third step:- checking for consistency
- Fourth step: - set up a triangular fuzzy number (TFN)
- Fifth step: - calculate the weight value of the fuzzy vector
- Sixth step: - ranking and selection of decisions

3.2. Mathematical model for weights analysis

Steps 1 and 2: If there are n elements that are compared, the comparison results create matrix form A with dimension n x m.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{n3} & a_{nm} \end{bmatrix}$$

The elements of the matrix or ratio between compared criteria are expressed by the formula: $a_{ij} = \frac{w_i}{w_j}$ Considering the first axiom for reciprocal have: $a_{ij} = \frac{1}{a_{ji}}$

The next step is to obtain a normalized matrix B $=[b_{ij}]$. The elements of the matrix B are calculated as: $b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$

The calculation of the weights i.e. eigenvector w $=w_i$, form the normalized matrix B is performed by calculating the arithmetic mean for each row of the matrix according to the formula: $w_i = \frac{\sum_{j=1}^{n} b_{ij}}{n}$

Step 3: Checking for consistency

Then calculate weighted sum value, $\sum w_i = \sum(a_{ij} * w_i)$ and divided the weighted sum value by the criteria weights $\frac{\sum w_i}{w_i}$ and find λ_{max}. $\lambda_{max} = \frac{\sum(\frac{\sum w_i}{w_i})}{n}$

The consistency index for a matrix is calculated from CI= (λ_{max} - n) / (n-1), and the consistency index can be expressed in the following way (Table 2):

Table 2. Consistency Index, RI, of random matrices

N		1	2	3	4	5	6	7	8	9	10
RI		0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Sources (Alkhamis, 2019; Rezaei, 2015)

Where n is the number of criteria or alternative.

Acceptability of alternative or attribute is measured in terms of Consistency Ratio (CR) = CI/RI. After calculation, the consistency ratio of each comparison matrix is found to be under 0.10. Therefore, we can conclude that the consistencies of the pairwise judgments in all matrices are acceptable

Step 4: Fuzzy AHP set up the triangular fuzzy number (TFN): In traditional AHP, a fundamental scale of 1 to 9 is used to decide the priority of one decision variable over another, which cannot handle uncertainty decisions in comparison of the attributes, whereas fuzzy AHP uses fuzzy numbers or linguistic variables. During AHP implementation, all comparisons may not include a certainty; therefore, more than the nine-point scale becomes necessary to describe the uncertainty. In this condition, to decide the priority of one decision variable over the other, linguistic variables and triangular fuzzy numbers can. The synthetic extent analysis method is used to decide the final priority weights based on triangular fuzzy numbers and so-called Fuzzy Extended AHP (FEAHP). Using a fuzzy AHP methodology for considering the lack of certainty and uncertainty existing in the judgment of the decision-maker(s), aggregated fuzzy pairwise matrix according to the corresponding triangular fuzzy numbers of the linguistic terms, the aggregate fuzzy pairwise matrix is explained in the following table 3.

Table 3. Aggregated fuzzy pairwise matrix

Intensity of Importance	Means	Fuzzy pairwise comparison matrix.
1	Equal	(1,1,1)
3	Moderate	(2,3,4)
5	Strong	(4,5.6)
7	Very strong	(6,7,8)
9	Extremely strong	(9,9,9)
2	Intermediate value	(1,2,3)
4		(3,4.5)
6		(5,6,7)
8		(7,8,9)
Sources: (Alkhamis, 2019; Kusumawardani & Agintiara, 2015; and Esmaili-dooki et al., 2017)		

Inverse: $\boldsymbol{A^{-1}} = (\boldsymbol{l},\ \boldsymbol{m},\ \boldsymbol{u})^{-1} = (\frac{1}{u}\ \ \frac{1}{m}, \frac{1}{l})$

Step 5: - calculate the weight value of the fuzzy vector: The geometric mean of fuzzy comparison values of each criterion are calculated using the following equation, where $\tilde{r}_i$ represents triangular values. $\tilde{A}_1 * \tilde{A}_2 = (l_1, m_1, u_1) * (l_2, m_2, u_2) = (l_1 * l_2,\ m_1 * m_2, u_1 * u_2)$

$$\tilde{r}_i = (\prod_{i}^{n} \tilde{a}_{ij})^{1/n}$$

The fuzzy weight ($\widetilde{w}_i$) of each criterion is calculated according to the Equation the following equation. This includes the replacement of the existing fuzzy triangular number with (-1) power of the summation vector of each $\tilde{r}_i$.

Fuzzy weights, $\widetilde{w}_i = \tilde{r}_i * (\tilde{r}_1 * \tilde{r}_2 * \tilde{r}_3 \ldots * \tilde{r}_n)^{-1}$, where

$(\tilde{r}_1 * \tilde{r}_2 * \tilde{r}_3 \ldots * \tilde{r}_n)^{-1} = \tilde{A}_1 * \tilde{A}_2 = (l_1, m_1, u_1) * (l_2, m_2, u_2) = (l_1 + l_2,\ m_1 + m_2, u_1 + u_2)$ and $A^{-1} = (l,\ m,\ u)^{-1} = (\frac{1}{u} \quad \frac{1}{m}, \frac{1}{l})$

Determination of non-fuzzy weight, the fuzzy triangular numbers $\widetilde{w}_i$ are defuzzified based on the Centre of area method (COA) using the following equation

$$M_i = \frac{l_{\widetilde{w}_i} + m_{\widetilde{w}_i} + u_{\widetilde{w}_i}}{3}$$

Computation normalized weight; the non-fuzzy number M_i is normalized by the following equation. The final score of each alternative is calculated by multiplying the weight of each alternative with related criteria.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}$$

Step 6: ranking and selection of decisions: The normalized weight of each criterion obtained from FAHP analysis is used for analyzing the alternative as weights to rank

3.2. Alternative Weight Analysis

Step 1: Fuzzy values in this matrix look at the scale of membership functions defined in the following table. The linguistics scale for each of the alternative are explaining below at Table 4.

Table 4. Linguistics scale for each of the selected alternative

Crisp Value	Linguistic Variable	Membership Function
1	Very low	(1 , 1, 3)
3	Low	(1, 3, 5)
5	Average	(3, 5, 7)
7	High	(5, 7, 9)
9	Very high	(7, 9, 9)

Sources (Alkhamis, 2019; Rezaei, 2015; Davim, 2015; Kusumawardani & Agintiara, 2015)

$\tilde{x} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$ and $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$

where

$a_{ij} = {}^{min}_{k}(b_{ij}{}^{k})$, $b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}{}^{k}$, $c_{ij} = {}^{max}_{k}(c_{ij}{}^{k})$

Step 2: Construct the normalized matrix

For getting a comparable scale, a linear scale transformation is used for positive and negative indicators, respectively:

$\tilde{R} = [\tilde{r}_{ij}]_{nxm}$

$\tilde{r}_{ij} = (\frac{a_{ij}}{c_{ij}{}^*}, \frac{b_{ij}}{c_{ij}{}^*}, \frac{c_{ij}}{c_{ij}{}^*})$, …, $c_j{}^*$=max c_{ij} (benefit criteria)…, i =1,2,3…,n, j=1,2,3…m

$\tilde{r}_{ij} = (\frac{a_j{}^-}{c_{ij}}, \frac{a_j{}^-}{b_{ij}}, \frac{a_j{}^-}{a_{ij}})$, …, $a_j{}^*$=min a_{ij} (cost criteria)…, i=1,2,3…,n, j=1,2,3…m

Step 3: Construct the weighted normalized matrix

Supposed that $\widetilde{w_j} = (\widetilde{w_1}, \widetilde{w_2}\, \widetilde{w_3} \ldots, \widetilde{w_n})$ is the weight importance of decision-makers and $\sum_{j=1}^{n} \widetilde{w_j} = 1$. $\tilde{v} = [\widetilde{v_{ij}}]_{n\,x\,m}$ is the weighted normalized matrix where i =1, 2, 3…, n, j=1, 2, 3…m, and it can be computed by utilizing the following equation

$\tilde{v}_{i\,j} = \tilde{r}_{i\,j} * \widetilde{w}_j$

Step 4. Calculate the fuzzy positive (FIPS) and fuzzy negative ideal solution (FNIS)

The FPIS and FNIS for alternatives can be determined as follow, respectively:

$\boldsymbol{A^{*}} = (\tilde{v}_1^{*}, \tilde{v}_2^{*}, \ldots, \tilde{v}_n^{*})$ **j= 1, 2, ….,n** and $\boldsymbol{A^{-}} = (\tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots \tilde{v}_n^{-})$ **j= 1, 2, ….,n**

Step 5. Calculating the distance of each choice from FPIS ($\boldsymbol{A^{*}}$) and FNIS ($\boldsymbol{A^{-}}$)

Calculating the distance of each weighted alternatives from FPIS and FNIS is possible by following equations:

$s_i^{*} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{*})$ **i =1, 2… m** and $s_i^{-} = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{-})$ **i =1, 2… m**

Step 6: Calculating each alternative closeness coefficient (cc_i^{*})

Closeness Coefficient (cc_i^{*}) represents the similarity to the ideal solution and it can be determined as follows: $(cc_i^{*}) = \left(\frac{s_i^{-}}{s_i^{*} + s_i^{-}}\right)$

Step 7: Ranking the alternatives: Ranking the different alternatives by utilizing (cc_i^{*}) on a decreasing order.

4. RESULTS AND DISCUSSION

4.1. Initial Data for FAHP Evaluation of alternative critical weight

Depending on the following steps the analysis is done:

AHP Step 1: The problem is decomposed into a hierarchy of goals, criteria, sub-criteria, and alternatives. The problem is the selection of the best garment production system, has eight criteria such as Transportation time, throughput time, WIP Level, Labor skill, Inventory Level, Space utilization, Quality control level, and Product flexibility, and the alternative production system are Progressive Bundling System (PBS), Make through System (MTS), Straight line system (SLS), Unit Production System (UBS) and Modular Production System (MPS) Figure 3.

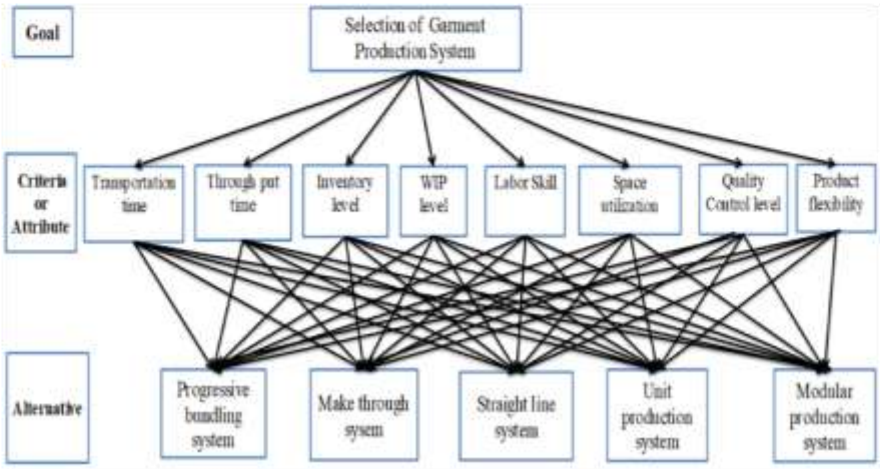


Figure 3. Analytical hierarchy of production system selection

4.2. Data collected for the Criterion Analysis of weight

Data are collected from experts or decision-makers corresponding to the hierarchic structure, the pair-wise comparison matrix is created with the help of the scale of relative importance. Experts like production managers, supervisors, and garment IE can rate the comparison as equally marginally strong, strong, very strong, and extremely strong. The data are collected depending on the Intensity of the importance of questioner for the selected sample garment companies (Table 5).

Table 5. Data collection

A		Transportation time	Throughput time	Inventory Level	WIP Level	Labor skill	Space Utilization	Quality control level	Product flexibility	Sum	Average
1	Transportation time	1	0.50	0.333	0.33	0.5	2	2	0.500	0.607	0.0679
2	Throughput time	2.00	1	0.33333	0.33333	3	0.5	0.500	0.500	0.67216144	0.07513131
3	Inventory Level	3.00	3.00	1	0.5	3	3	3	2	1.987013346	0.22209979
4	WIP Level	3.00	3.00	2.000	1	4	2	3	2	2.32844	0.2603
5	Labor skill	2.00	0.33	0.333	0.25	1	2	2	3	0.95058	0.1063
6	Space utilization	0.50	2.00	0.333	0.50	0.5	1	2	0.333	0.69677	0.0779
7	Quality control level	0.50	2.00	0.3333	0.333	0.5	0.50	1	0.333	0.55695747	0.0622543
8	Product flexibility	2.00	2.00	0.50000	0.50000	0.33333	3.00000	3	1	1.14720269	0.1282294
Sum										8.9464892	1

Consistency checking is a mechanism for checking whether rules do not contain semantically conflicting elements (Table 6). Ambiguities can be found either in a single rule or in a set of rules. Acceptability of alternative or attribute is measured in terms of Consistency Ratio (CR) =CI/RI. After calculation, the consistency ratio of each comparison matrix is found to be under 0.10. Therefore, we can conclude that the consistencies of the pairwise judgments in all matrices are acceptable

Table 6. Checking for consistency

	Transportation time	**Through-Put time**	**Inventory Level**	**WIP Level**	**Labor skill**	**Space Utilization**	**Quality control level**	**Product flexibility**	**Sum**	**Average**
Transportation time	0.0679	0.03757	0.07403	0.08675	0.05313	0.15576	0.12451	0.06411	0.6638	9.77709806
Through put time	0.1358	0.07513	0.07403	0.08675	0.31876	0.03894	0.03113	0.06411	0.8246	10.9759093
Inventory Level	0.2037	0.22539	0.22210	0.13013	0.31876	0.23365	0.18676	0.25646	1.7769	8.0005246
WIP Level	0.2037	0.22539	0.44420	0.26026	0.42501	0.15576	0.18676	0.25646	2.1575	8.28976686
Labor skill	0.1358	0.02504	0.07403	0.06507	0.10625	0.15576	0.12451	0.38469	1.0711	10.0810902
Space utilization	0.0339	0.02504	0.07403	0.13013	0.05313	0.07788	0.12451	0.04274	0.5614	7.20848119
Quality control level	0.0339	0.15026	0.07403	0.08675	0.05313	0.03894	0.06225	0.04274	0.5421	8.7071703
Product flexibility	0.1358	0.15026	0.11105	0.13013	0.03542	0.23365	0.18676	0.12823	1.1113	8.6663259
Sum										71.70637
Average (λ_{max})										8.963296
Subtract ((λ_{max} - n) where n=8										0.963296
CI ((λ_{max} - n) / (n-1)										0.137614

CR = CI / CI constant from matrix < 0.1 must be for consistency of the matrix CR= $\frac{\mathbf{0.137614}}{\mathbf{1.41}}$ < 0.1=**0.09760 < 0.1** it is true, Therefore, conclude that the consistencies of the pairwise judgments in all matrices are acceptable then the next step proceed

Table 7. Fuzzification process of critical weight analysis

Fuzzification is the process of converting a crisp input value to a fuzzy value that is performed by the use of the information in the knowledge base. Although various types of curves can be seen in literature, Gaussian, triangular, and trapezoidal MFs are the most commonly used in the fuzzification process (Table 7).

	Fuzzification																							
	Transportation time			**Through put time**			**Inventory Level**			**WIP Level**			**Labor skill**			**Space Utilization**			**Quality control level**			**Product flexibility**		
	U	M	l	U	M	l	U	M	l	U	M	L	U	M	l	u	M	l	u	M	l	U	M	L
Transportation time	1	1	1	0.333	0.5	1	0.25	0.333	0.5	0.25	0.33333	0.5	0.333	0.5	1	1	2	3	1	2	3	0.333	0.500	1
Through put time	1	2	3	1	1	1	0.25	0.333	0.5	0.25	0.33333	0.5	2	3	4	0.3333	0.5	1	0.3333	0.5	1	0.333	0.500	1
Inventory Level	2	3	4	2	3	4	1	1.000	1	0.333	0.5	1	2	3	4	2	3	4	2	3	4	1.000	2.000	3
WIP Level	2	3	4	2	3	4	1	2.000	3	1	1	1	3	4	5	1	2	3	2	3	4	1.000	2.000	3
Labor skill	1	2	3	0.25	0.33	0.5	0.25	0.333	0.5	0.2	0.25	0.33333	1	1	1	1	2	3	1	2	3	2.000	3.000	4
Space utilization	0.333	0.5	1	1	2	3	0.25	0.333	0.5	0.333	0.5	1	0.333	0.5	1	1	1	1	1	2	3	0.250	0.333	0.5
Quality control level	0.333	0.5	1	1	2	3	0.25	0.333	0.5	0.25	0.33333	0.5	0.333	0.5	1	0.3333	0.5	1	1	1	1	0.250	0.333	0.5
Product flexibility	1	2	3	1	2	3	0.333	0.500	1	0.333	0.5	1	0.25	0.3333	0.5	2	3	4	2	3	4	1.000	1.000	1

The geometric mean of fuzzy comparison values of each criterion is calculated using the following equation, where $\tilde{r}_i$ represents triangular values

$$\tilde{A}_1 * \tilde{A}_2 = (l_1, m_1, u_1) * (l_2, m_2, u_2) = (l_1 * l_2, m_1 * m_2, u_1 * u_2)$$

$$\tilde{r}_i = (\prod_{i}^{n} \tilde{a}_{ij})^{1/n}$$

The fuzzy weight ($\widetilde{w}_i$) of each criterion is calculated according to the Equation the following equation. This includes the replacement of the existing fuzzy triangular number with (-1) power of the summation vector of each $\widetilde{r}_i$. Fuzzy weights, $\widetilde{w}_i = \widetilde{r}_i * (\tilde{r}_1 * \tilde{r}_2 * \tilde{r}_3 \ldots * \tilde{r}_n)^{-1}$, where $(\tilde{r}_1 * \tilde{r}_2 * \tilde{r}_3 \ldots * \tilde{r}_n)^{-1} = \tilde{A}_1 * \tilde{A}_2 = (l_1, m_1, u_1) * (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$ and $A^{-1} = (l, m, u)^{-1} = (\frac{1}{u} \frac{1}{m}, \frac{1}{l})$. Determination of non-fuzzy weight, the fuzzy triangular numbers $\widetilde{w}_i$ are de-fuzzified based on the Centre of area method (COA) using the following equation $M_i = \frac{l_{\widetilde{w}_i} + m_{\widetilde{w}_i} + u_{\widetilde{w}_i}}{3}$. Computation normalized weight; the non-fuzzy number M_i is normalized by the following equation. The final score of each alternative is calculated by multiplying the weight of each alternative with related criteria. $N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}$

Table 8. Fuzzified Pair-wise Comparison Matrix

	Fuzzified Pair-wise Comparison Matrix											
	The fuzzy geometric mean value				Fuzzy weights							
	U	M	L	U	M	L	L	M	U			
				6.064	9.163	13	0.0763	0.109	0.165	COA	Weights	Normalize
												Weights
Transportation time	0.468	0.7	1.11				0.0357	0.076	0.183	0.2943	0.0981	0.0884
Through put time	0.511	0.8	1.15				0.039	0.087	0.189	0.31541	0.10514	0.0948
Inventory Level	1.344	1.99	2.73				0.1026	0.217	0.45	0.76943	0.25648	0.2312
WIP Level	1.488	2.33	3.11				0.1136	0.254	0.217	0.58471	0.1949	0.1757
Labor skill	0.631	0.95	1.32				0.0481	0.104	0.217	0.36891	0.12297	0.1108
Space utilization	0.468	0.7	1.11				0.0357	0.076	0.183	0.2943	0.0981	0.0884
Quality control level	0.394	0.56	0.88				0.0301	0.061	0.146	0.23673	0.07891	0.0711
Product flexibility	0.76	1.15	1.71				0.058	0.125	0.281	0.46466	0.15489	0.1396
										Sum	1.109	1

Implementation of the FAHP method to attain the final ranking results (Table 8): This paper identified different effective factors in productivity for improvement used for production system performance analysis need, which was studied in the Ready-Made Garments (RMGs) sector in Ethiopia. Depending on the analysis of the FAHP method the major factors are explained in the following ways:

1st:- Inventory Level, 2nd:- WIP Level, 3rd; - Product flexibility, 4th:- Labor skill, 5th:- Throughput time, 6th:- Transportation time and Space utilization, and 7th:- Quality control level. The figure 4 explain the summary of the criteria in ranking order of the criteria weights.

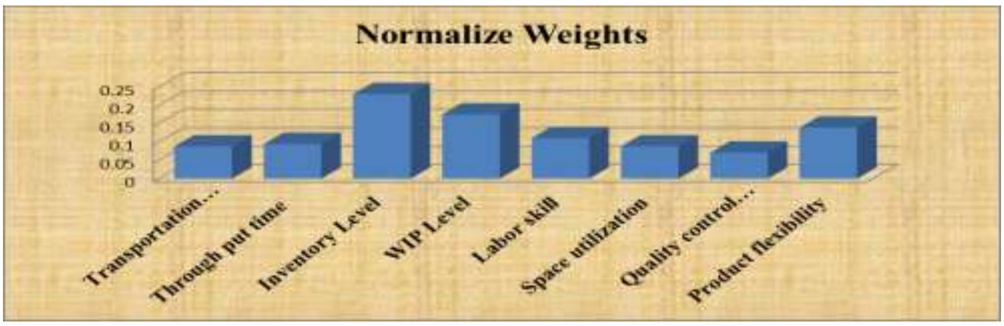


Figure 4. Normalized weight of each criterion

4.3. Alternative weight analysis of production system selection

Fuzzy TOPSIS needs information about the relative importance of each alternative for weighting. The alternatives are:- Progressive Bundling System (PBS), Make through System (MTS), Straight line system (SLS), Unit Production System (UBS), and Modular Production System (MPS) after comparison analysis of each factor concerning in each production system types then calculate.

Calculating the distance of each weighted alternatives from FPIS and FNIS is possible by the following equations: $\boldsymbol{s_i}^{*}=\sum_{j=1}^{n} \boldsymbol{d}(\tilde{\boldsymbol{v}}_{i\,j},\ \tilde{\boldsymbol{v}}_j^{\,*})$ **i =1, 2… m and** $\boldsymbol{s_i}^{-}=\sum_{j=1}^{n} \boldsymbol{d}(\tilde{\boldsymbol{v}}_{i\,j},\ \tilde{\boldsymbol{v}}_j^{\,-})$ **i =1, 2… m.** Calculating each alternative closeness coefficient ($cc_i^{\,*}$) Closeness Coefficient ($cc_i^{\,*}$) represents the similarity to the ideal solution and it can be determined as follows: $(\boldsymbol{cc_i}^{*}) = \left(\frac{s_i^{-}}{s_i^{*}\ +\ s_i^{-}}\right)$

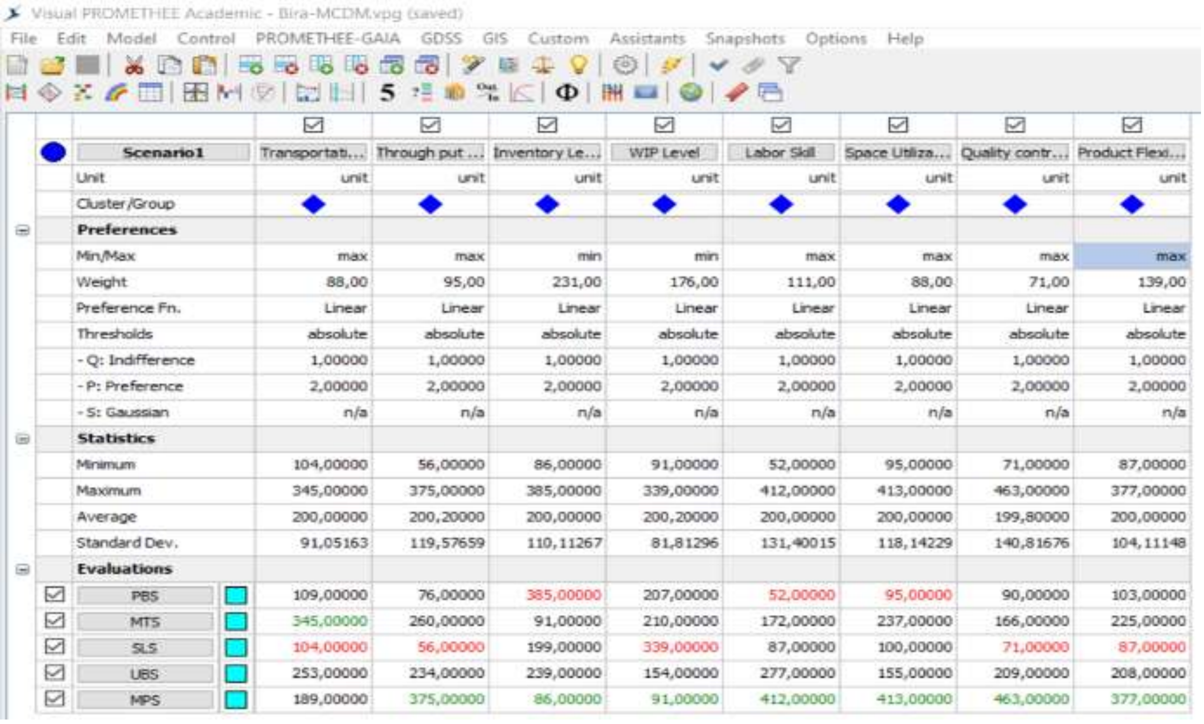
Table 9:-Alternative Weight Analysis of PS

	Weight of all criteria	PBS	MTS	SLS	UBS	MPS
Transportation time	0.0884 18873	0.1093 03416	0.3454 07476	0.1036 9213	0.253 057776	0.1885392
Through put time	0.0947 61593	0.0755 11118	0.2597 58411	0.0556 9057	0.2337 76712	0.375263192
Inventory Level	0.2311 69035	0.3853 4174	0.0905 1746	0.1992 5872	0.2390 96983	0.085785096
WIP Level	0.1756 69478	0.2065 57491	0.2102 46934	0.338 52501	0.1540 15751	0.090654815
Labor skill	0.1108 36004	0.0520 10392	0.171 754959	0.087 25344	0.2765 93902	0.412387306
Space utilization	0.0884 18873	0.0949 63743	0.236 85838	0.1001 8016	0.155 180253	0.412817468
Quality control level	0.0711 2299	0.0900 87454	0.165 626797	0.0711 1074	0.209 945043	0.463229967
Product flexibility	0.1396 03156	0.1032 6508	0.224 619721	0.087 30198	0.207 611364	0.377201856

Based on the analysis FAHP and FTOPSIS for the selection of the best garment production system based on the eight criteria, the result of the analysis is explained in ranks, The 1st:- Modular Production System (MPS), the 2nd:- Unit Production System (UBS) The 3rd:- Make through System (MTS), the 4th:- Progressive Bundling System (PBS), and the 5th:- Straight line system (SLS). The figure 5 shows the summary of the production system in ranking order. Snapshot of window Visual PROMETHEE software is presented on Figure 6.

Figure 5. Normalized weight of each Alternative PS

Depending on the analysis of Visual PROMETHEE is multi-criteria decision aid (MCDA) software figure 6.



Scenario1	Transportati...	Through put ...	Inventory Le...	WIP Level	Labor Skill	Space Utiliza...	Quality contr...	Product Flexi...
Unit	unit	unit	unit	unit	unit	unit	unit	unit
Cluster/Group								
Preferences								
Min/Max	max	max	min	min	max	max	max	max
Weight	88,00	95,00	231,00	176,00	111,00	88,00	71,00	139,00
Preference Fn.	Linear	Linear	Linear	Linear	Linear	Linear	Linear	Linear
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000	1,00000
- P: Preference	2,00000	2,00000	2,00000	2,00000	2,00000	2,00000	2,00000	2,00000
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics								
Minimum	104,00000	56,00000	86,00000	91,00000	52,00000	95,00000	71,00000	87,00000
Maximum	345,00000	375,00000	385,00000	339,00000	412,00000	413,00000	463,00000	377,00000
Average	200,00000	200,20000	200,00000	200,20000	200,00000	200,00000	199,80000	200,00000
Standard Dev.	91,05163	119,57659	110,11267	81,81296	131,40015	118,14229	140,81676	104,11148
Evaluations								
PBS	109,00000	76,00000	385,00000	207,00000	52,00000	95,00000	90,00000	103,00000
MTS	345,00000	260,00000	91,00000	210,00000	172,00000	237,00000	166,00000	225,00000
SLS	104,00000	56,00000	199,00000	339,00000	87,00000	100,00000	71,00000	87,00000
UBS	253,00000	234,00000	239,00000	154,00000	277,00000	155,00000	209,00000	208,00000
MPS	189,00000	375,00000	86,00000	91,00000	412,00000	413,00000	463,00000	377,00000

Figure 6. Snapshot of window Visual PROMETHEE software

Walking weights analysis of visual PROMETHEE MCDM depending on transportation time for example explains the following 7.

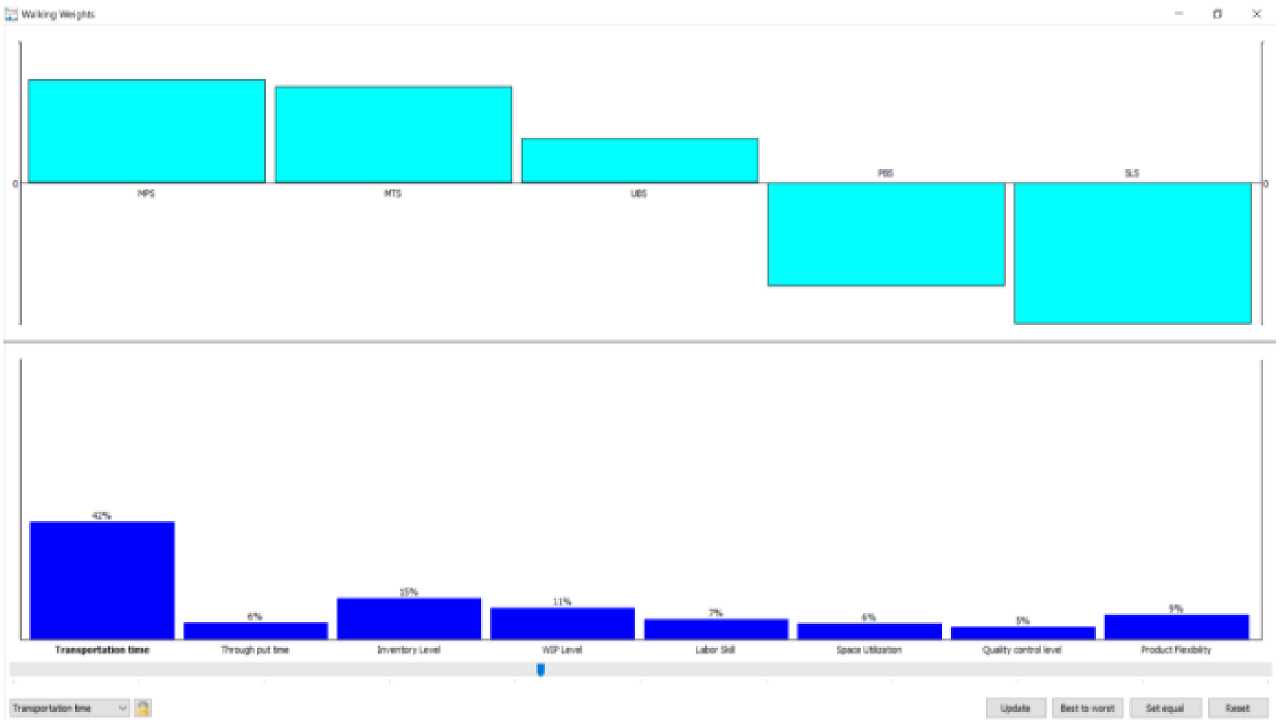


Figure7. PROMETHEE Rainbow Analysis

It seems that a modular production system is a perfect solution for the garment manufacturer to minimize work in process inventory, minimize wastes, improve production process, and respond to the quick replenishment requirement by the retailers.

5. CONCLUSION

In any production-related company, the enhancement of productivity is of great importance. This paper identified different effective factors affecting productivity and selection of the best practices production system by using MCDM; four-phased research method has been projected to find out some governing factors affecting the garment manufacturing industry's output and, evaluation of the factors affecting productivity improvement.

In the first phase, eight criteria associated with productivity have been identified based on literature, inputs from experts, opinions from the officials and managers in the garment manufacturing industry of Ethiopia. In the second phase, the Fuzzy Analytic Hierarchy Process (FAHP) has been used for evaluating criteria weights and ranking the criteria. 1st:- Inventory Level, 2nd:- WIP Level, 3rd; - Product flexibility, 4th:- Labor skill, 5th:- Throughput time, 6th:- Transportation time and Space utilization, and 7th:- Quality control level. Among eight criteria, low inventory level control and work in progress criterion have been found as the most important factor to improve the productivity of garment manufacturing industries.

In the third phase, five alternative production systems have been identified, and Fuzzy TOPSIS has integrated the factors for selection of the best practices of the production system, based on the analyzing FAHP and FTOPSIS for the selection of the best garment production system based on the eight criteria, the result of the analysis is explained in ranks, The 1st:- Modular Production System (MPS), the 2nd:- Unit Production System (UBS) The 3rd:- Make through System (MTS), the 4th:- Progressive Bundling System (PBS), and the 5th:- Straight line system (SLS). Among the alternative, the best one is the modular production system.

A module is a team of workers assigned to the production of a specific product, organized so that the product flows in a quick and synchronized way according to the order of its operations.

To achieve it, it is necessary to estimate the production times for each operation and by the application of mathematical expressions, it can be arrived in a model of distribution of workloads or modular balance, looking for the appropriate use of the human factor, machines, and space.

5.1 Future Research Area

There are different factors it could be external factors and internal factors that it exists in garment manufacturing industries further can be studied by increasing the number of factors and with related to other departments of the garment from each factor by using FAHP and FTOPSIS or other Multi-Criteria Decision Making (MCDM) tools to show the problem in detail.

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