LAPORAN AKHIR PENELITIAN

HIBAH KERIS-DIMAS

JUDUL PENELITIAN:

OPTIMASI SISTEM PENGAMBILAN KEPUTUSAN SEBAGAI PENDUKUNG PENGEMBANGAN USAHA DI BIDANG AGROINDUSTRI

KELOMPOK RISET-DIMAS

MATHEMATICAL OPTIMIZATION AND COMPUTATION (MOCo)

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RINGKASAN

Dalam setiap perusahaan pasti **memerlukan beberapa sistem untuk membantu berjalannya suatu proses** yang ada dalam perusahaan tersebut. Salah satu proses yang terdapat dalam perusahaan adalah **proses pengambilan keputusan**. **Tujuan pengambilan keputusan** yang dilakukan adalah: untuk mengidentifikasi apa yang harus dikerjakan, mengembangkan kriteria khusus untuk mencapai tujuan, mengevaluasi alternatif yang tersedia yang berhubungan dengan kriteria dan mengidentifikasi risiko yang melekat pada keputusan tersebut. Situasi pada saat mengambil keputusan dibedakan menjadi: ada kepastian, ada risiko, tidak ada kepastian, dan ada konflik.

Pengembangan usaha adalah penciptaan jangka panjang bagi organisasi dari pelanggan, pasar, dan interaksi di dalamnya. Hal ini berarti **pengembangan usaha bertujuan** untuk mempertahankan usaha agar tetap produktif dan menghasilkan keuntungan dalam jangka panjang. Sejak berdirinya PT Bank Syariah Indonesia (BSI), digadang-gadang bakal meningkatkan pasar keuangan syariah Indonesia di mata dunia. Permasalahan pandemik Covid-19, membuat situasi yang tak menentu dari situasi yang pasti menjadi situasi yang tidak pasti dan cenderung chaos. Hal ini membuat BSI melakukan pengembangan usaha yang dilakukan secara terus menerus. Begitu juga dalam strategi pengembangan usahanya. Bank tesebut juga melakukan empat strategi pengembangan usaha. **Hal-hal yang dilakukan oleh Bank Syariah Indonesia dalam pengembangan usahanya seperti: penentuan lokasi yang tepat baik outlet/kantor cabang pembantu, penentuan lokasi anjungan tunai mandiri (ATM), penyediaan produk tabungan yang bervariasi serta pendanaan bagi usaha-usaha yang bergerak di bidang agroindustry.** Tujuan akhir dari beberapa hal tersebut adalah kepuasan pada nasabah.

Untuk membantu pengembangan usaha PT Bank Syariah Indonesia khususnya Cabang Jember, maka metode yang digunakan dalam penelitian disesuaikan dengan situasi pengambilan keputusannya. Metode tersebut adalah ***Analytical Hierarchy Process*** **(AHP),** ***Fuzzy, Fuzzy Analytic Hierarchy Process*** **ataupun** ***Fuzzy C-Means***. Selanjutnya, **tujuan khusus** dari penelitian ini adalah adanya keinginan untuk berkontribusi terhadap pengembangan riset di bidang teknologi dan informasi khususnya perbankan untuk **memberikan alternative system pengambilan keputusan yang tepat**. Oleh karena itu, apa yang akan dikembangkan dalam kegiatan penelitian ini menjadi penting dalam mendukung pengambilan kebijakan secara tepat.

Hasil Penelitian dan Status Luaran sampai dengan Laporan Kemajuan ini dibuat, yaitu telah dibuat 7 (tujuh) artikel dengan 3 (tiga) diantaranya disajikan dalam Seminar Internasional. Sedangkan Status Luaran: Terbit pada S2, Proses Review pada S2, S4, S5, prosiding internasional iora jurnal conference dan prosiding seminar ICON SMART.

Rencana Lanjutan/khusus dari penelitian ini adalah merevisi dan memantau artikel yang dalam proses review sampai dengan terbit serta menyelesaikan draft artikel yang telah dibuat agar dapat masuk ke jurnal sesuai rencana sebelumnya. **Rencana secara umum** yang berkaitan dengan Kelompok Riset adalah secara rutin akan mengikuti hibah internal yang diselenggarakan oleh LP2M Universitas Jember dan makain meningkatkan kedalaman penelitian dan keluasan tersebarnya hasil penelitian.

DAFTAR ISI

BAB 1. PENDAHULUAN

A. Latar Belakang

Dalam setiap perusahaan pasti memerlukan beberapa sistem untuk membantu berjalannya suatu proses yang ada dalam perusahaan tersebut. Salah satu proses yang terdapat dalam perusahaan adalah proses pengambilan keputusan. **Proses pengambilan keputusan ini sangat penting** dalam sebuah perusahaan, karena pengambilan keputusan harus dilakukan secara benar agar tidak terjadi kesalahan pada masa yang akan datang, karena setiap keputusan yang diambil akan sangat mempengaruhi proses kedepannya. **Pengambilan Keputusan adalah** sebuah proses memilih tindakan dari berbagai alternatif untuk mencapai suatu/beberapa tujuan. **Tujuan pengambilan keputusan** yang dilakukan adalah: untuk mengidentifikasi apa yang harus dikerjakan, mengembangkan kriteria khusus untuk mencapai tujuan, mengevaluasi alternatif yang tersedia yang berhubungan dengan kriteria dan mengidentifikasi risiko yang melekat pada keputusan tersebut. Situasi pada saat mengambil keputusan dibedakan menjadi: ada kepastian, ada risiko, tidak ada kepastian, dan ada konflik.

Pengembangan usaha adalah penciptaan jangka panjang bagi organisasi dari pelanggan, pasar, dan interaksi di dalamnya. Hal ini berarti **pengembangan usaha bertujuan** untuk mempertahankan usaha agar tetap produktif dan menghasilkan keuntungan dalam jangka panjang. Ada **dua jenis** pengembangan usaha, yaitu: **Pengembangan Vertikal** dan **Pengembangan Horizontal**. **Strategi pengembangan us**aha harus dilakukan dari **segi produk, sistem penjualan, integrasi, dan sinergisme**.[1].

Penguatan keberadaan perbankan di Indonesia semakin masif sejak dikeluarkan Undang-Undang Nomor 10 Tahun 1998 tentang Perubahan Undang-Undang No. 7 Tahun 1992 Pasal 1 tentang Perbankan. Eksistensi Bank Syariah di Indonesia didorong dengan munculnya Undang-Undang tersebut dan keinginan kuat masyarakat.[2]. Menurut [3] kondisi fluktuatif akibat Covid-19 tidak menempatkan perbankan syariah pada keterpurukan. Perbankan syariah masih menunjukkan kinerja positif dengan strategi dan inovasi baru serta mitigasi risiko yang tepat dan cermat. Kementerian Badan Usaha Milik Negara (BUMN) memaksimalkan potensi perbankan syariah dengan menggabungkan tiga bank BUMN yaitu PT Bank Syariah Mandiri, PT Bank Rakyat Indonesia Syariah, dan PT Bank BNI Syariah Penggabungan ketiga bank syariah ini kemudian disebut dengan PT Bank Syariah Indonesia (BSI) Tbk. Manfaat dari penggabungan ketiga bank ini jelas dapat menaikkan asset secara otomatis dan lebih dipercaya oleh masyarakat.

Sejak berdirinya PT Bank Syariah Indonesia (BSI) pada tanggal 1 Februari 2021, digadang-gadang bakal meningkatkan pasar keuangan syariah Indonesia di mata dunia. Permasalahan pandemik Covid-19, membuat situasi yang tak menentu dari situasi yang pasti menjadi situasi yang tidak pasti dan cenderung chaos. Hal ini membuat BSI melakukan pengembangan usaha yang dilakukan secara terus menerus. Pengembangan Usaha oleh PT Bank Syariah Indonesia (BSI) Tbk tak lepas dari pengembangan usaha vertikal dan pengembangan usaha horizontal. Begitu juga dalam strategi pengembangan usahanya. Bank tesebut juga melakukan empat strategi pengembangan usaha. **Hal-hal yang dilakukan oleh Bank Syariah Indonesia dalam pengembangan usahanya seperti: penentuan lokasi yang tepat baik outlet/kantor cabang pembantu, penentuan lokasi anjungan tunai mandiri (ATM), penyediaan produk tabungan yang bervariasi serta pendanaan bagi usaha-usaha yang bergerak di bidang agroindustry. Tujuan akhir dari beberapa hal tersebut adalah kepuasan pada nasabah.**

B. Perumusan Masalah

Penelitian ini merupakan **penelitian dasar dengan TKT 3** (*proof-of-concept*) secara analitis dan eksperimental, yang termasuk dalam roadmap KeRis Mathematical Optimization and Computation (MOCo) untuk Sistem Pengambilan Keputusan, Roadmap KeRis disajikan pada Gambar 1.

Gambar 1. Roadmap Penelitian KeRis MOCo 2018-2025

Selain masuk dalam Roadmap Kelompok Riset, juga sesuai dengan riset unggulan dalam RIPP (Rencana Induk Penelitian Dan Pengabdian Kepada Masyarakat) Universitas Jember 2021-2025 difokuskan dalam 9 (sembilan) riset unggulan yang berwawasan lingkungan, bisnis, dan pertanian industrial. **Penelitian ini masuk dalam bidang Riset Unggulan ke-5 yaitu Teknologi Informasi dan Komunikasi dengan tema Sistem Informasi Pertanian**

Industrial dan sub tema dalam bentuk Sistem Pendukung Pengambilan Keputusan (*Decision Support System*) Untuk Agroindustri.[4]

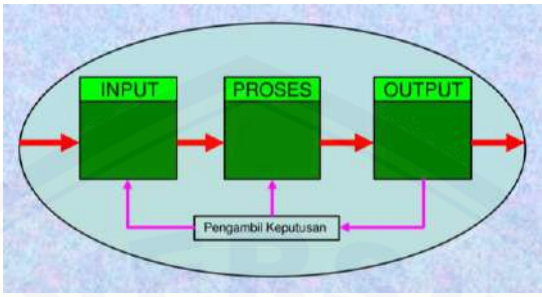
C. Tujuan dan Manfaat Penelitian

Metode yang akan digunakan dalam penelitian untuk membantu pengembangan usaha PT Bank Syariah Indonesia khususnya Cabang Jember, disesuaikan dengan situasi pengambilan keputusannya. Metode tersebut adalah *Analytical Hierarchy Process* (AHP), *Fuzzy*, *Fuzzy Analytic Hierarchy Process* ataupun *Fuzzy C-Means*. Selanjutnya, tujuan khusus dari penelitian ini adalah adanya keinginan untuk berkontribusi terhadap pengembangan riset di bidang teknologi dan informasi khususnya perbankan untuk memberikan alternative system pengambilan keputusan yang tepat. Oleh karena itu, apa yang akan dikembangkan dalam kegiatan penelitian ini menjadi penting dalam mendukung pengambilan kebijakan secara tepat.

BAB 2. KERANGKA TEORI

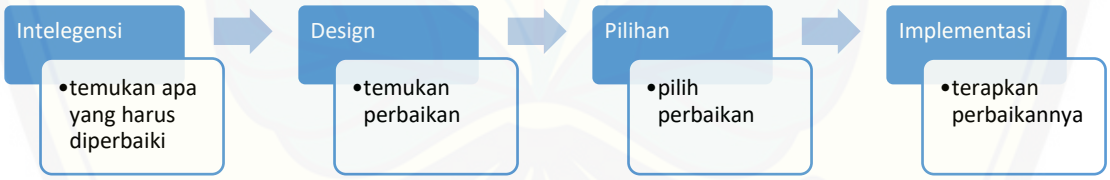
A. Sistem Pengambilan Keputusan

Sistem adalah kumpulan unsur-unsur yang ada dalam lingkup permasalahan yang saling berintegritas dengan tujuan yang terarah pada satu tujuan yang pasti. Struktur sistem (Gambar 2) dibagi menjadi 3 bagian yaitu masukan (*input*), proses (*process*), dan keluaran (*output*).[5,6]



Gambar 2. Struktur sistem

Pengambilan Keputusan adalah sebuah proses memilih tindakan dari berbagai alternatif untuk mencapai suatu/beberapa tujuan. Proses pengambilan keputusan (Gambar 3) melalui 4 fase yaitu : (1) Inteligensi, (2) Design, (3) Pilihan, dan (4) Implementasi. [7]. Sedangkan Disiplin ilmu yang diperlukan dalam Pengambilan Keputusan dipengaruhi langsung oleh: Disiplin Perilaku (antropologi, hukum, filsafat, psikologi, sosiologi) dan Disiplin Ilmiah (matematika, statistik, riset operasi, ekonomi, teknik, ilmu computer, ilmu pasti, analisa keputusan). Matematika sebagai salah satu bidang ilmu berada dalam ranah disiplin ilmiah.[8].



Gambar 3. Proses pengambilan keputusan

Tujuan pengambilan keputusan yang dilakukan adalah: untuk mengidentifikasi apa yang harus dikerjakan, mengembangkan kriteria khusus untuk mencapai tujuan, mengevaluasi alternatif yang tersedia yang berhubungan dengan kriteria dan mengidentifikasi risiko yang melekat pada keputusan tersebut. Situasi pada saat mengambil keputusan dibedakan menjadi:[8]

1. Ada kepastian (*Certainty*): Jika semua informasi yg diperlukan untuk membuat keputusan diketahui secara sempurna & tdk berubah,

2. Ada risiko (*Risk*) : Jika informasi sempurna tidak tersedia, tetapi seluruh peristiwa yg akan terjadi besarta probabilitasnya diketahui,
3. Tidak ada kepastian (*Uncertainty*): Jika seluruh informasi yg mungkin terjadi diketahui, tetapi tanpa mengetahui probabilitasnya masing-masing, dan
4. Ada konflik (*Conflict*): Jika kepentingan dua/lebih pengambil keputusan berada dlm pertarungan aktif diantara kedua belah pihak

Menurut [5,6] Sistem Pendukung Keputusan memiliki beberapa keuntungan, diantaranya adalah :

1. Memperluas kemampuan pengambil keputusan dalam memproses data atau informasi untuk pengambil keputusan.
2. Menghemat waktu yang dibutuhkan untuk memecahkan masalah, terutama masalah yang kompleks.
3. Menghasilkan solusi dengan lebih cepat dan hasilnya dapat diandalkan.
4. Memberikan berbagai alternatif dalam pengambilan keputusan.
5. Memperkuat keyakinan pengambil keputusan.
6. Memberikan keuntungan kompetitif bagi organisasi secara keseluruhan dengan penghematan waktu, tenaga, dan biaya.

B. Pengembangan Usaha

Pengembangan usaha adalah penciptaan jangka panjang bagi organisasi dari pelanggan, pasar, dan interaksi di dalamnya. Hal ini berarti pengembangan usaha bertujuan untuk mempertahankan usaha agar tetap produktif dan menghasilkan keuntungan dalam jangka panjang. Ada dua jenis pengembangan usaha, yaitu [1]:

1. Pengembangan Vertikal adalah pengembangan usaha dengan cara mengembangkan inti dari bisnis; dan
2. Pengembangan Horizontal adalah pengembangan bisnis yang tidak linear dengan inti bisnis, namun dapat memperkuat inti bisnis tersebut.

Strategi pengembangan usaha harus dilakukan dari 4 (empat) segi [1]

1. segi produk, pengembangan usaha dilakukan dengan cara mengembangkan produk sesuai dengan selera pasar, mengeluarkan produk baru yang inovatif, mencari cara efisien dalam produksi sehingga produk berkualitas sama bisa dihasilkan dengan biaya yang lebih rendah.
2. segi penjualan, pengembangan usaha dilakukan dengan membangun hubungan yang baik dengan konsumen, melakukan penjualan melalui media sosial, memastikan kepuasan konsumen,

3. Integrasi adalah mengembangkan bisnis dengan cara memperbesar perusahaan. Misalnya suatu perusahaan pembuat makanan ringan berupa keripik membeli toko baru sebagai cabang, membeli perkebunan kentang untuk bahan baku, membeli perusahaan ekspedisi untuk distribusi bahan baku dan pemasaran produk, serta membeli perusahaan percetakan untuk menunjang kemasan dari produk.
4. Sinergisme adalah membangun sinergi di dalam perusahaan dan memperluas jejaring sosial di luar perusahaan. Sinergisme dapat dibangun dengan merekrut pegawai yang memiliki bakat dari bidang usaha, bekerja sama dengan perusahaan lokal maupun nasional untuk membuka pasar baru, dan memperluas jangkauan pasar.

C. Metode *Analytical Hierarchy Process* (AHP)

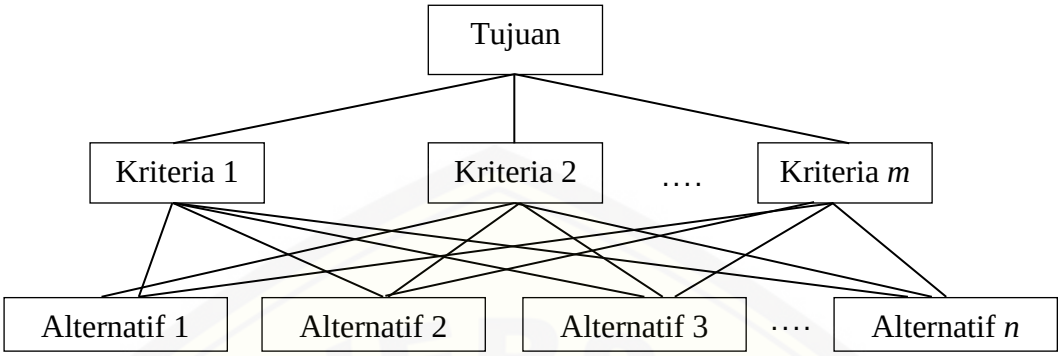
Analytical Hierarchy Process (AHP) merupakan metode yang digunakan untuk meranking alternatif keputusan dalam memilih satu alternatif keputusan terbaik saat pembuat keputusan tersebut memiliki berbagai kriteria. Peralatan utama dari metode AHP adalah hirarki fungsional dimana *input* utamanya merupakan perspektif manusia. Suatu masalah kompleks dan tidak terstruktur diselesaikan kedalam kelompok-kelompok yang kemudian dijabarkan menjadi suatu bentuk hirarki. Tujuan yang bersifat umum dapat dijabarkan ke dalam beberapa sub tujuan yang lebih terperinci yang menjelaskan apa yang dimaksud dalam tujuan pertama. Penjabaran dapat dilakukan terus sehingga akhirnya diperoleh tujuan yang bersifat operasional. Pada hirarki terendah ini dilakukan proses evaluasi atas alternatif-alternatif yang merupakan ukuran dari pencapaian tujuan utama dan juga dapat ditetapkan dalam satuan apa kriteria diukur. Metode AHP sering digunakan sebagai metode penyelesaian masalah dibanding dengan metode yang lain karena alasan-alasan sebagai berikut [9,10]:

1. Struktur yang berhirarki, sebagai konsekuensi dari kriteria yang dipilih sampai pada subkriteria yang paling rendah.
2. Memperhitungkan validitas sampai dengan batas toleransi inkonsistensi berbagai kriteria dan alternatif yang dipilih oleh pengambil keputusan.
3. Memperhitungkan daya tahan *output* analisis sensivitas pengambilan keputusan.
4. Namun, metode AHP memililiki kelemahan dalam sistem analisisnya, yaitu:
5. Ketergantungan model AHP pada input utamanya yang berupa persepsi seorang ahli, sehingga dalam hal ini melibatkan kesubyektifitas sang ahli. Selain itu juga model menjadi tidak berarti jika ahli tersebut memberikan penilaian yang keliru.
6. Metode AHP hanyalah metode matematis tanpa adanya pengujian secara statistik sehingga tidak ada batas kepercayaan dari kebenaran model yang terbentuk.

Menurut [9,10], langkah-langkah dalam metode AHP adalah sebagai berikut:

1. **Menyusun struktur hirarki permasalahan.**

   Hirarki permasalahan digunakan untuk mempertimbangkan kriteria-kriteria pendukung dalam mencapai tujuan (Gambar 4)



Gambar 4. Struktur hirarki permasalahan metode AHP

2. **Penilaian kriteria dan alternatif dengan melakukan perbandingan berpasangan**

   Skala penilaian perbandingan permasalahan pada metode AHP bernilai 1 hingga 9 (Tabel 1). Perbandingan dua elemen yang sama akan menghasilkan angka 1. Elemen yang akan dibandingkan disusun dalam matriks perbandingan berpasangan antar kriteria dan matriks perbandingan berpasangan antar alternatif yang ditunjukkan pada Tabel 2 dan Tabel 3.

Tabel 1. Skala penilaian metode AHP

Tingkat Kepentingan	Definisi	Keterangan
1	Kedua elemen sama Pentingnya	Kedua elemen seimbang sama besar pada sifat tersebut
3	Elemen yang satu sedikit lebih penting daripada elemen lainnya	Keputusan sedikit memihak pada satu elemen
5	Elemen yang satu lebih penting dari pada elemen lainnya	Keputusan sangat kuat memihak pada satu elemen
7	Satu elemen jelas lebih penting daripada elemen lainnya	Keputusan menunjukkan secara kuat disukai dan didominasi satu elemen yang sangat jelas lebih penting
9	Satu elemen mutlak penting daripada elemen lainnya	Keputusan menujukkan satu elemen sangat jelas lebih penting
2, 4, 6, 8	Nilai tengah diantara dua penilaian yang berdampingan	Nilai ini diberikan bila ada dua kompromi diantara 2 pilihan
Kebalikan	Bila elemen ke-ij pada faktor i mendapatkan nilai-nilai x maka elemen ke-ij pada faktor ke-j mendapatkan nilai $1/x$	

Tabel 2. Matriks perbandingan berpasangan antar kriteria (K_i)

K	K_1	K_2	$\cdots$	K_i
K_1	k_{11}	k_{12}	$\cdots$	k_{1i}
K_2	k_{21}	k_{22}	$\cdots$	k_{2i}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
K_i	k_{i1}	k_{i2}	$\cdots$	k_{ii}

Tabel 3. Matriks perbandingan berpasangan antar alternatif (A_j)

K_i	A_1	A_2	$\cdots$	A_j
A_1	a_{11}	a_{12}	$\cdots$	a_{1j}
A_2	a_{21}	a_{22}	$\cdots$	a_{2j}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_j	a_{j1}	a_{j2}	$\cdots$	a_{jj}

Keterangan:

K : kriteria

K_i : kriteria ke-i, i = 1,2,…, m

k_{ii} : nilai perbandingan elemen K_i (baris) terhadap K_i(kolom) yang menyatakan tingkat kepentingan K_i (baris) dibanding K_i (kolom)

A : alternatif

A_j : alternatif ke-j, j = 1,2,…, n

a_{jj}: nilai perbandingan elemen A_j (baris) terhadap A_j (kolom) yang menyatakan tingkat kepentingan A_j (baris) terhadap K_i kriteria dibandingkan dengan A_j (kolom)

3. Menentukan Prioritas

Prioritas lokal dari matriks perbandingan berpasangan yang terbentuk dicari dengan menggunakan nilai vektor eigen. Prioritas lokal adalah relatif pentingnya elemen terendah pada hirarki dibandingkan dengan kriterianya.

4. Menguji Konsistensi Logis

Konsistensi perbandingan ditinjau dari setiap matriks perbandingan dan keseluruhan hirarki untuk memastikan urutan prioritas yang dihasilkan didapat dari suatu rangkaian perbandingan yang masih berada pada batas preferensi logis. Tujuan dari dilakukannya pengujian konsistensi logis adalah untuk menghindari penilaian preferensi seseorang yang menyimpang dan tidak konsisten.

D. Logika Fuzzy

Logika fuzzy diperkenalkan oleh Lotfi A. Zadeh, pengajar di University of California di Barkeley pada tahun 1965. Logika *fuzzy* merupakan suatu cara pemrosesan data menggunakan serangkaian himpunan keanggotaan, yang terinspirasi dari proses persepsi dan penalaran manusia. Menurut [11] logika *fuzzy* digunakan karena beberapa alasan berikut:

1. Konsepnya matematisnya sangat sederhana sehingga mudah dimengerti
2. Memiliki toleransi terhadap data-data yang tidak tepat.
3. Sangat fleksibel.
4. Didasarkan pada bahasa yang alami.

Pada himpunan *fuzzy*, nilai keanggotaan terletak pada rentang 0 sampai 1. Himpunan *fuzzy* memiliki dua variabel, yaitu linguistik dan numerik. Linguistik dinyatakan dengan penamaan suatu kelompok atau grup dalam suatu kondisi menggunakan bahasa alami, seperti tinggi, rendah, tua, muda dan lain-lain. Numerik merupakan suatu angka yang menyatakan nilai untuk menunjukkan ukuran variabel seperti 5, 18, 42 dan lain-lain.[13].

E. *Fuzzy Analytical Hierarchy Process* (F-AHP)

Metode *Fuzzy Analytical Hierarchy Process* (F-AHP) pertama kali diusulkan oleh seorang peneliti bernama Chang dan merupakan perpanjangan atau ekstensi dari metode AHP yang diciptakan oleh Saaty yang terdiri dari unsur-unsur matriks yang diwakili oleh bilangan *fuzzy*. Chang mendefinisikan nilai intensitas AHP ke dalam skala *fuzzy* segitiga yaitu membagi tiap himpunan *fuzzy*, *Triangular Fuzzy Number* (TFN) dan kebalikan. Metode *extent analysis* digunakan untuk nilai sintesis pada perbandingan berpasangan pada F-AHP. Nilai *Fuzzy Synthetic Extent* digunakan untuk mendapatkan nilai matriks perbandingan dengan menilai bobot setiap kriteria terhadap tujuan utama dari hirarki sehingga nilai *extent analysis* dapat ditunjukkan sebagai $M_{gi_1}, M_{gi_2}, \dots M_{gi_m}, i = 1,2, \dots, n$, dimana $M_{gi_1}^{j} (j = 1,2, \dots, m)$ adalah bilangan *Triangular Fuzzy Number* (TFN). Skala *fuzzy* segitiga (TFN) dan variabel linguistiknya sesuai dengan skala Saaty dapat dilihat pada Tabel 4 [11]:

Tabel 4. Skala *triangular fuzzy number*

Definisi	Skala Saaty	TFN	Invers Skala Saaty
Sama penting	1	(1,1,1)	(1,1,1)
Sedikit lebih penting	3	(1, 3/2, 2)	(1/2, 2/3, 1)
Lebih penting	5	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Sangat penting	7	(3, 7/2, 4)	(1/4, 2/7, 1/3)
Mutlak lebih penting	9	(4, 9/2, 9/2)	(2/9, 2/9, 1/4)
Nilai yang berdekatan	2	(1/2, 1, 3/2)	(2/3, 1, 2)

	4	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
	6	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
	8	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

F. *Fuzzy C Means*

Fuzzy C Means (FCM) merupakan salah satu algoritma *clustering* data. FCM diperkenalkan oleh Jim Bezdek pada tahun 1981. Metode ini termasuk suatu teknik pengklusteran data yang keberadaan tiap titik-titik data dalam *cluster* ditentukan oleh derajat keanggotaan. Teknik ini menggunakan penerapan pengelompokan *fuzzy*, dimana setiap data dapat menjadi dari beberapa anggota *cluster* dengan derajat keanggotaan yang berbeda pada setiap *cluster*. FCM menerapkan iterasi pada proses *clustering* data. Tujuan dari *fuzzy c means* untuk memperoleh pusat *cluster* yang digunakan untuk mengetahui data yang masuk pada sebuah *cluster*. [11]. Menurut [11], algoritma *Fuzzy C-Means* (FCM) adalah sebagai berikut:

1. Memasukkan data yang akan di*cluster* dalam sebuah matriks X, berupa matriks berukuran $n \times m$, dengan n jumlah data yang akan di*cluster*, m atribut setiap data dan X_{ij} : data sampel ke-i ($i = 1,2,3, \dots, n$), atribut ke-j ($j = 1,2,3, \dots, m$)

2. Menentukan jumlah *cluster* yang akan dibentuk (c), pangkat atau pembobot (w), maksimal iterasi (MaksIter), eror terkecil yang diharapkan (ε), fungsi objektif awal ($P_0 = 0$), iterasi awal ($t = 1$).

3. Membangkitkan setiap jumlah kolom (atribut):

$$Q_j = \sum_{k=1}^{c} \mu_{ik}$$

untuk $i = 1,2, \dots, n$; $k = 1,2, \dots, c$; dan $j = 1,2, \dots, m$ dengan Q_j jumlah perkalian dari setiap kolom, μ_{ik} derajat keanggotaan dari X_i, dimana bentuk matriks partisi awal U sebagai berikut:

$$U = \begin{bmatrix} \mu_{11}(x_1) & \mu_{12}(x_2) & \dots & \mu_{1c}(x_c) \\ \mu_{21}(x_1) & \mu_{22}(x_2) & \dots & \mu_{2c}(x_c) \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{n1}(x_1) & \mu_{n2}(x_2) & \dots & \mu_{nc}(x_c) \end{bmatrix}$$

Persamaan di atas menjelaskan matriks awal yang terbentuk dari setiap data akan di inputkan ke dalam perhitungan. Jumlah *cluster* yang akan dibentuk digambarkan oleh $\mu_{11}(\mu_1)$ sampai dengan $\mu_{1c}(x_c)$, sedangkan jumlah dari data yang akan di *cluster* digambarkan oleh $\mu_{11}(\mu_1)$ sampai dengan $\mu_{n1}(x_1)$. Dimana $0 < \mu_{ik} < 1$ dan jumlah setiap kolom pada matriks U harus sama dengan 1.

4. Menghitung pusat *cluster* V, untuk setiap *cluster*

$$V_{kj} = \frac{\sum_{i=1}^{n}(\mu_{ik})^{w} * X_{ij}}{\sum_{i=1}^{n}(\mu_{ik})^{w}}$$

untuk $k = 1,2,\dots,c$ dan $j = 1,2,\dots,m$ dengan V_{kj} pusat *cluster*, ${\mu_{ik}}^{w}$ matriks U dipangkatkan pembobot, X_{ij} sampel data ke-i pada variabel ke-j, w pangkat (pembobot)

5. Menghitung fungsi objektif pada iterasi ke-t, P_t:

Fungsi objektif digunakan sebagai syarat perulangan agar mendapatkan pusat *cluster* yang tepat. Nilai iterasi awal $t = 1$

$$P_t = \sum_{i=1}^{n}\sum_{k=1}^{c}\left(\left[\sum_{j=1}^{m}\left(X_{ij} - V_{kj}\right)^2\right](\mu_{ik})^{w}\right)$$

dengan $i = 1,2,\dots,n$; $k = 1,2,\dots,c$; dan $j = 1,2,\dots,m$ dimana P_t fungsi objektif, X_{ij} sampel data ke-i pada variabel ke-j, V_{kj} nilai pusat *cluster* ke-k pada variabel ke-j, c jumlah *cluster* yang berada di dalam X, n jumlah data yang diproses, w pangkat (pembobot)

6. Menghitung perubahan matriks partisi pada setiap data pada setiap *cluster*

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]^{\frac{-1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]^{\frac{-1}{w-1}}}$$

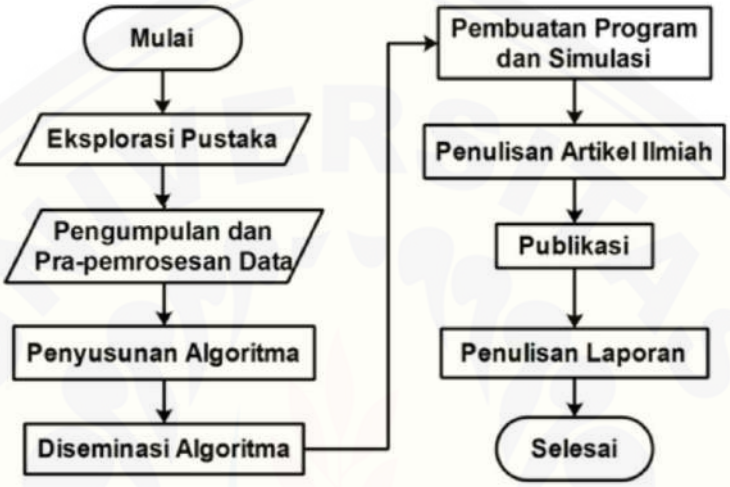
untuk i=1,2,…,n dan $k = 1,2,\dots,c$ dengan m banyak variabel dengan ($j = 1,2,3,\dots,m$), X_{ij} sampel data ke-i pada variabel ke-j, V_{kj} nilai pusat *cluster* ke-k pada variabel ke-j

7. Melakukan pengecekan kondisi berhenti

1) Jika ($|P_t - P_{t-1}| < \varepsilon$) atau ($t >$ MaksIter) maka berhenti;
2) Jika tidak $t = t + 1$, maka mengulangi langkah ke-4, dengan P_t fungsi objektif, ε eror terkecil yang diharapkan, t iterasi awal

BAB 3. METODE PENELITIAN

Penelitian ini menggunakan metode penelitian analisis dan eksperimental untuk mendapatkan hasil dari metode yang digunakan yaitu *Analytical Hierarchy Process* (AHP), *Fuzzy*, *Fuzzy Analytic Hierarchy Process* ataupun *Fuzzy C-Means* dengan berbantukan perangkat lunak Matlab. Rancangan penelitian yang digunakan untuk menghasilkan algoritma yang diusulkan disajikan pada Gambar 1 berikut:



Gambar 1. Skema metode penelitian

BAB 4. HASIL YANG DICAPAI

A. Hasil Penelitian dan Pembahasan

Beberapa metode analisis keputusan dapat digunakan untuk penentuan lokasi usaha. Metode tersebut adalah : *Pertama* ***Analytical Hierarchy Process*** **(AHP**) yang digunakan untuk meranking alternatif keputusan dalam memilih satu alternatif keputusan terbaik saat pembuat keputusan tersebut memiliki berbagai kriteria. Suatu masalah kompleks dan tidak terstruktur diselesaikan kedalam kelompok-kelompok yang kemudian dijabarkan menjadi suatu bentuk hirarki. Tujuan yang bersifat umum dapat dijabarkan ke dalam beberapa sub tujuan yang lebih terperinci yang menjelaskan apa yang dimaksud dalam tujuan pertama. Penjabaran dapat dilakukan terus sehingga akhirnya diperoleh tujuan yang bersifat operasional. Pada hirarki terendah ini dilakukan proses evaluasi atas alternatif-alternatif yang merupakan ukuran dari pencapaian tujuan utama dan juga dapat ditetapkan dalam satuan apa kriteria diukur. *Kedua* Metode ***Fuzzy Analytical Hierarchy Process*** **(F-AHP)** merupakan perpanjangan atau ekstensi dari metode AHP yang terdiri dari unsur-unsur matriks yang diwakili oleh bilangan *fuzzy*. Nilai intensitas AHP dimasukkan ke dalam skala *fuzzy* segitiga yaitu membagi tiap himpunan *fuzzy*, *Triangular Fuzzy Number* (TFN) dan kebalikan, dan *Ketiga* ***Fuzzy C Means*** **(FCM)** merupakan salah satu algoritma *clustering* data. Metode ini termasuk suatu teknik pengklusteran data yang keberadaan tiap titik-titik data dalam *cluster* ditentukan oleh derajat keanggotaan. Teknik ini menggunakan penerapan pengelompokan *fuzzy*, dimana setiap data dapat menjadi dari beberapa anggota *cluster* dengan derajat keanggotaan yang berbeda pada setiap *cluster*. FCM menerapkan iterasi pada proses *clustering* data. Tujuan dari *fuzzy c means* untuk memperoleh pusat *cluster* yang digunakan untuk mengetahui data yang masuk pada sebuah *cluster*.

B. Status Luaran Penelitian

Hasil Penelitian dan Status Luaran, yaitu telah dibuat 7 (tujuh) artikel dengan 3 (tiga) diantaranya disajikan dalam Seminar Internasional. (Bukti terlampir)

1. Barekeng : Jurnal Ilmu Matematika dan Terapan (S2) - Vol 16 No 3 (2022**)** (https://ojs3.unpatti.ac.id/index.php/barekeng) - **TERBIT**

   Analytical Hierarchy Process in Determining Level The Feasibility of The Automated Teller Machine Location
2. The 3rd International Conference On Natural Sciences Mathematics, Applications, Research, and Technology (ICON SMART 2022) **– ACCEPTED** a**vailable online at https://aip.scitation.org/ on October 2023.**

Strategical Level Assessment of Bank Offices Location using Analytical Hierarchy Process Method

3. The 3rd International Conference On Natural Sciences Mathematics, Applications, Research, and Technology (ICON SMART 2022) **– PROSES REVIEW**
   Application of Multiple Objective Programming Method for Optimization and Sensitivity Analysis of Furniture Production
4. Cauchy : Jurnal Matematika Murni Dan Aplikasi (S2) (ejournal.uin-malang.ac.id/index.php/Math) **– PROSES REVIEW**
   Recommendations For Bank Savings Using The Fuzzy Analytical Hierarchy Process Method
5. Jurnal Matematika Sains dan Teknologi (S4) (jurnal.ut.ac.id/index.php/jmst) **– PROSES REVIEW**
   Penentuan Lokasi Atm Bank Syariah Indonesia Menggunakan Metode Fuzzy C Means Di Kabupaten Jember
6. IORA-International Conference on Operations Research IORA-ICOR (iorajournal.org/index.php/orics) **– PROSES REVIEW**
   Application of Metaheuristic Algorithm for Solving Fully Fuzzy Linear Equations System
7. Draft rencana akan disubmit Jurnal Matematika FMIPA Universitas Udayana (S5) (ojs.unud.ac.id/index.php/jmat) - **DRAFT**
   Penerapan *Analytical Hierarchy Process* Dalam Penentuan Kelayakan Produksi (Studi Kasus : Produksi Susu Argopuro Probolinggo)
8. Konferensi Nasional Matematika (KNM) **XXI – PROSES REVIEW**
   Application of Markov Chain in Predicting Sugar Production at Candi Baru Sugar Factory, Sidoarjo

BAB 5. KESIMPULAN DAN SARAN

Salah satu tujuan pengambilan keputusan dalam perusahaan adalah mengevaluasi alternatif yang tersedia yang berhubungan dengan kriteria dan mengidentifikasi risiko yang melekat pada keputusan tersebut. Situasi pada saat mengambil keputusan dibedakan menjadi: ada kepastian, ada risiko, tidak ada kepastian, dan ada konflik. Sedangkan **pengembangan usaha bertujuan** untuk mempertahankan usaha agar tetap produktif dan menghasilkan keuntungan dalam jangka panjang. Salah satu hal **yang dilakukan oleh Bank Syariah Indonesia dalam pengembangan usahanya adalah penentuan lokasi yang tepat baik outlet/kantor cabang pembantu, penentuan lokasi anjungan tunai mandiri (ATM)**, dengan tujuan akhir dari hal tersebut adalah kepuasan pada nasabah. **Untuk membantu pengembangan usaha PT Bank Syariah Indonesia khususnya Cabang Jember**, maka metode yang dapat digunakan adalah ***Analytical Hierarchy Process* (AHP), *Fuzzy*, *Fuzzy Analytic Hierarchy Process* ataupun *Fuzzy C-Means***. Metode tersebut **memberikan alternative system pengambilan keputusan yang tepat**.

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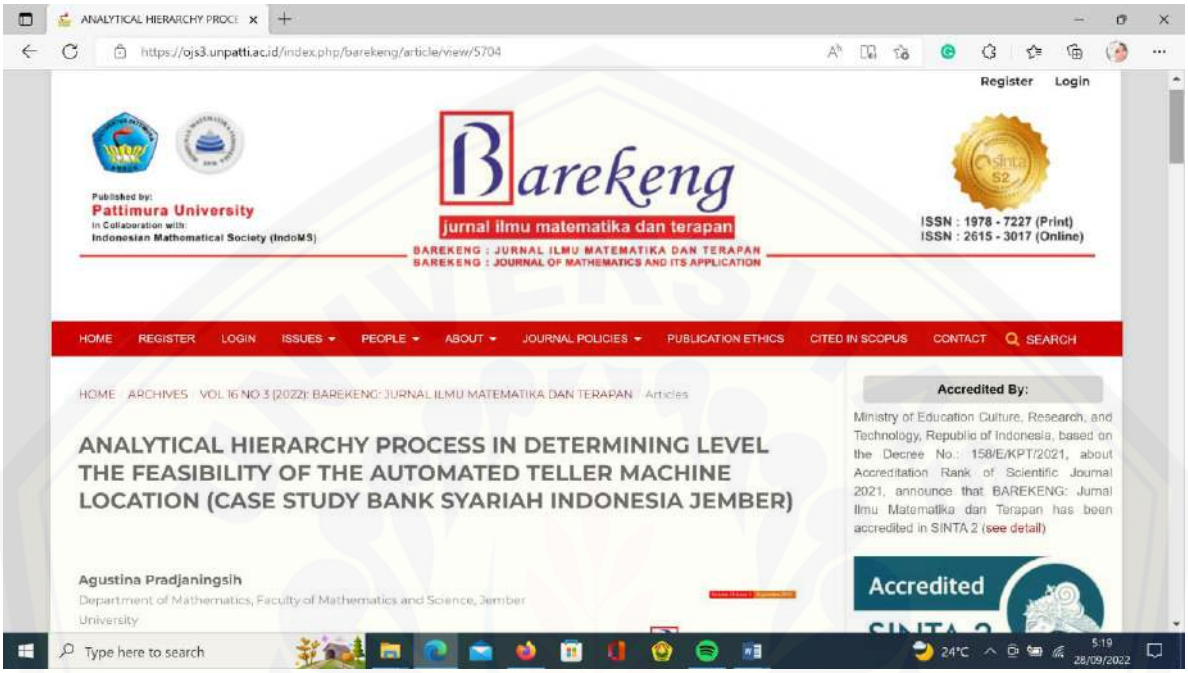
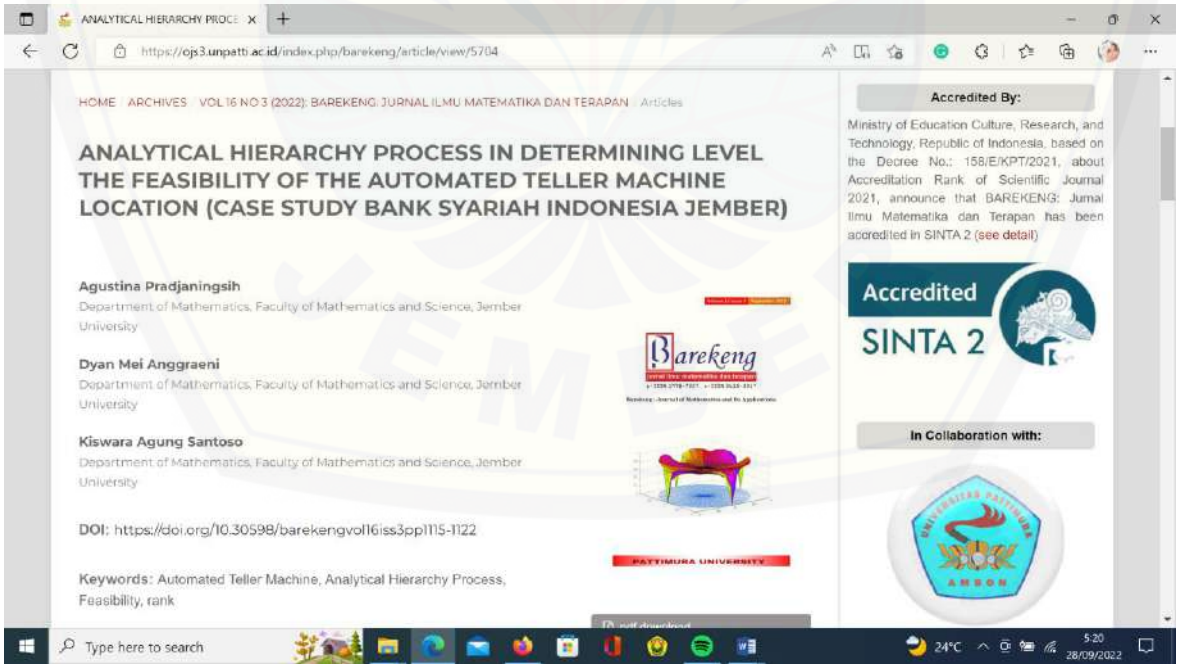
LAMPIRAN

Lampiran 1. Bukti Terbit/Submit/Proses Review Artikel

1. Barekeng : Jurnal Ilmu Matematika dan Terapan (S2) - Vol 16 No 3 (2022**)** (https://ojs3.unpatti.ac.id/index.php/barekeng) - **TERBIT**

Analytical Hierarchy Process in Determining Level The Feasibility of The Automated Teller Machine Location





2. The 3rd International Conference On Natural Sciences Mathematics, Applications, Research, and Technology (ICON SMART 2022) **–**

A. *Strategical Level Assessment of Bank Offices Location using Analytical Hierarchy Process Method* - **ACCEPTED** a**vailable online at https://aip.scitation.org/ on October 2023.**

The 3rd International Conference on Natural Sciences, Mathematics, Applications, Research, and Technology (ICON-SMART 2022)
FACULTY OF MATHEMATICS AND NATURAL SCIENCES
UNIVERSITAS SAM RATULANGI
Kampus UNSRAT Manado 95115
E-mail: icon-smart@unsrat.ac.id; Website: http://www.icon-smart.org/

LETTER OF ACCEPTANCE

Dear:
Agustina Pradjaningsih
Department of Mathematics, Faculty of Mathematics and Natural Sciences, University of Jember, Jember, Indonesia

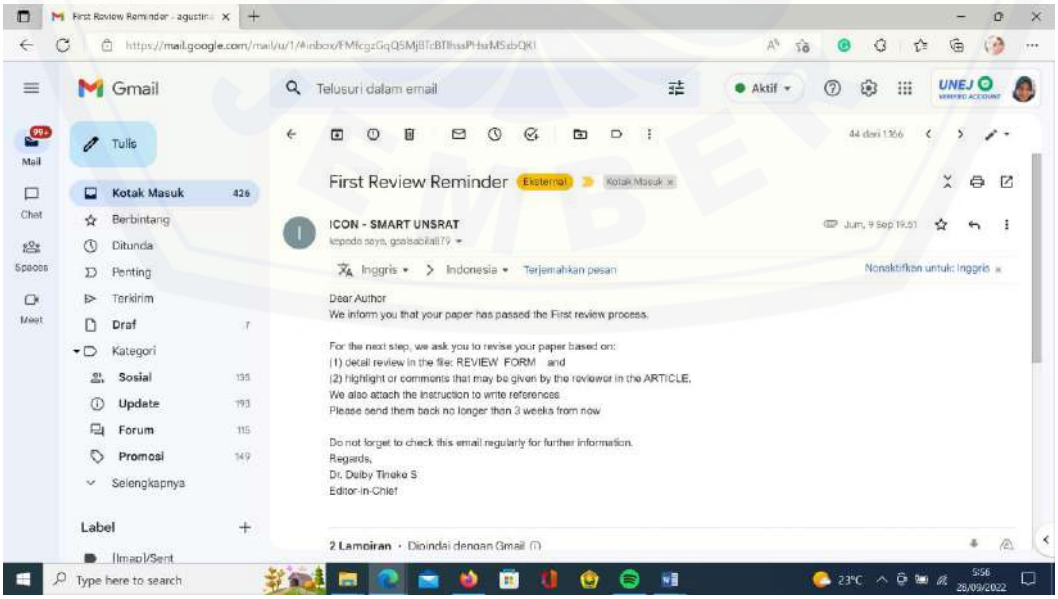
It is our pleasure to inform you that, after the peer review, your paper, **"Strategical Level Assessment of Bank Offices Location using Analytical Hierarchy Process Method"** has been **ACCEPTED** to be published in the **AIP Conference Proceedings** and it will be available online at https://aip.scitation.org/ on October 2023.

Thank you very much for participating in the Conference and submitting your work to this Proceedings. We hope you will participate in the next conference and submit your article in the future.

23rd November, 2022
Best regards,

Dr. Deiby Tineke Salaki
Editor-in-Chief

B. *Application of Multiple Objective Programming Method for Optimization and Sensitivity Analysis of Furniture Production* - **PROSES REVIEW**

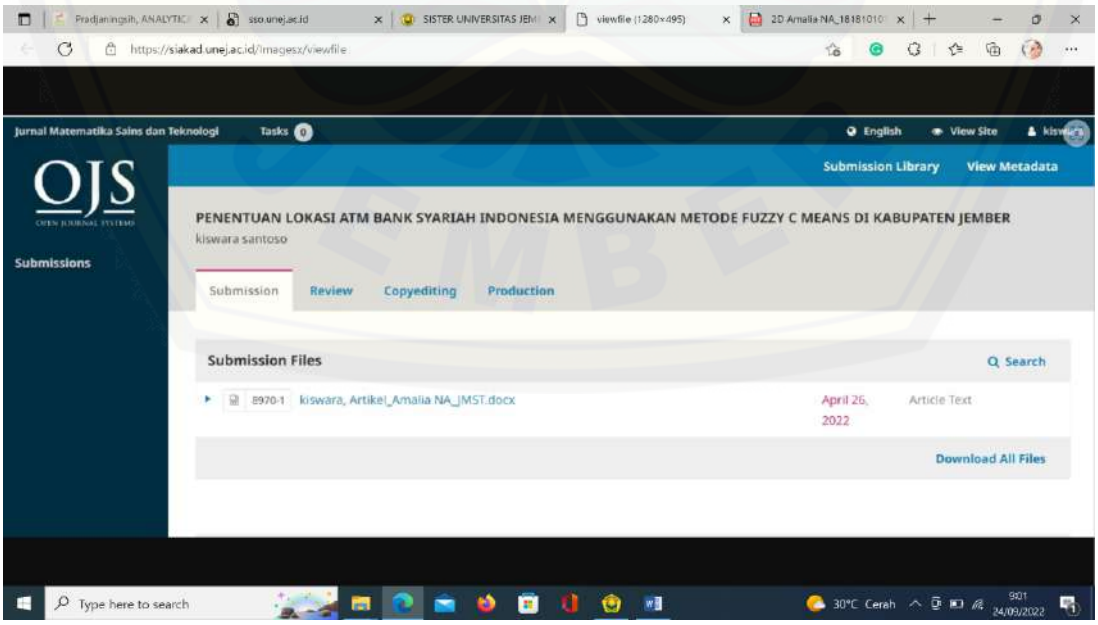


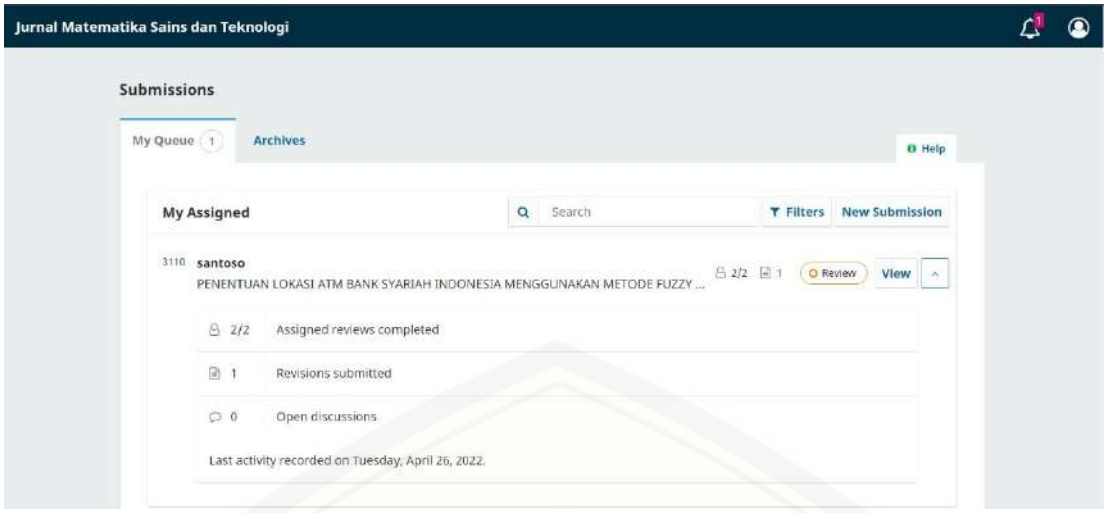
3. Cauchy : Jurnal Matematika Murni Dan Aplikasi (S2) (ejournal.uin-malang.ac.id/index.php/Math) **– PROSES REVIEW**

Recommendations For Bank Savings Using The Fuzzy Analytical Hierarchy Process Method

4. Jurnal Matematika Sains dan Teknologi (S4) (jurnal.ut.ac.id/index.php/jmst) **– PROSES REVIEW**

Penentuan Lokasi Atm Bank Syariah Indonesia Menggunakan Metode Fuzzy C Means Di Kabupaten Jember





5. IORA-International Conference on Operations Research IORA-ICOR (iorajournal.org/index.php/orics) **– PROSES REVIEW**
Application of Metaheuristic Algorithm for Solving Fully Fuzzy Linear Equations System

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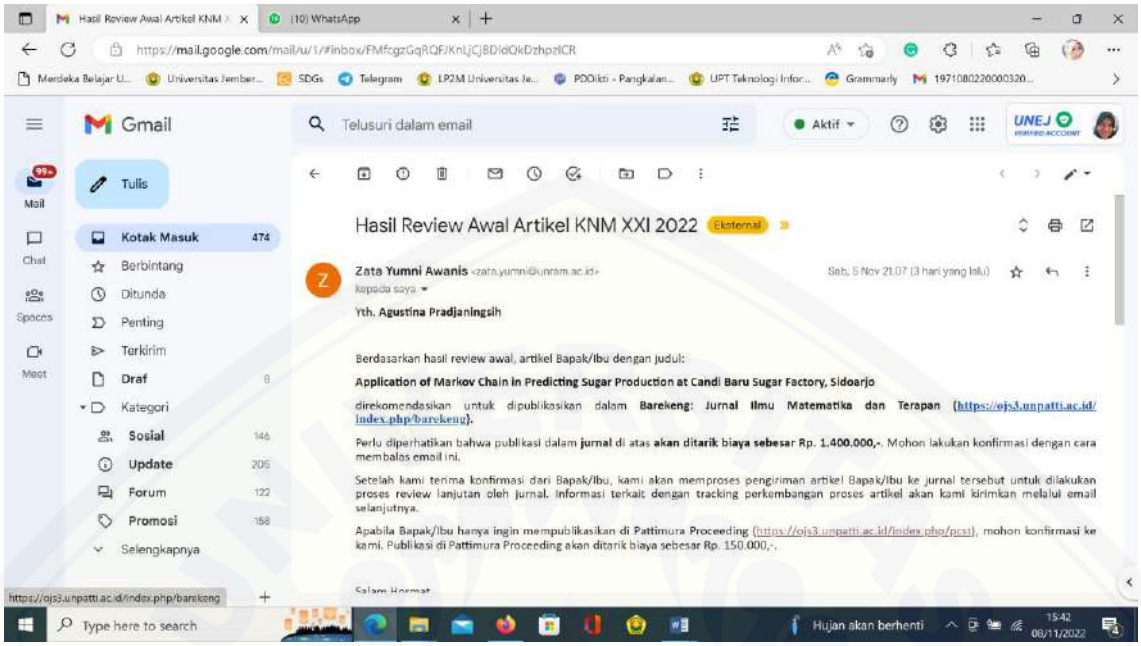
Application of Markov Chain in Predicting Sugar Production at Candi Baru Sugar Factory, Sidoarjo



Lampiran 2. Artikel

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ANALYTICAL HIERARCHY PROCESS IN DETERMINING LEVEL THE FEASIBILITY OF THE AUTOMATED TELLER MACHINE LOCATION (CASE STUDY BANK SYARIAH INDONESIA JEMBER)

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Abstract. *Bank Syariah Indonesia (BSI) is a new Islamic bank resulting from the merger of three Islamic banks. It requires developers to maximize the feasibility of the Automated Teller Machine (ATM) location. The placement of a proper ATM location can increase the bank's profits. This research was conducted to assist BSI Jember Regency in determining the feasibility level of 10 ATM locations that are already owned based on several criteria that have been selected. This study aimed to analyze the results of the feasibility of the BSI ATM location. The method used in this study was the Analytical Hierarchy Process (AHP) method. AHP is a method used to rank the best alternative decision from several criteria that must be met or considered. In this study, four criteria and ten alternatives were used. These criteria were the distance of the ATM from the center of the crowd (X1), the distance of the ATM from the security office (X2), the number of residents (X3), and the number of non-BSI ATMs (X4), while the alternatives were 10 BSI ATM locations. This study obtained the results of the location feasibility of the establishment of 10 BSI ATMs, with the BSI KKAS UNMUH ATM, which ranked first because it had the most considerable value of 0.1674.*

Keywords: *Automated Teller Machine, Analytical Hierarchy Process, Feasibility, Rank*

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1. INTRODUCTION

The development of an increasingly modern era makes people prefer to save money in banks because it is more secure than at home. Banks carry out various financial transactions such as securing money, remittances, making payments, or billing [1]. There are two types of banks in the banking world: conventional and Islamic. Conventional banks are banks that, in their activities, both in collecting and distributing funds, charge rewards in the form of interest within a certain period [2]. Islamic banks carry out their business activities based on sharia principles, namely the rules of agreements based on Islamic law [3]. Increasing industry competition has forced banks to find ways to provide excellent customer service, one of which is Automated Teller Machines (ATMs). ATM is one example of the development of information technology provided by banks as a substitute for tellers. It can serve various banking transactions such as transferring money, checking balance information, making payments, and withdrawing money [4]. Determining a business location is a decision that must be made carefully because it is closely related to the success of a business [5]. Determination of proper and appropriate ATM locations can increase transactions to increase bank profits [6]. Determining the location of ATMs that meet the criteria can also help banks in global banking competition [7]. The increasingly fierce global banking competition requires banks to make decisions to determine ATM locations more quickly. The decision-making can be done using the Analytical Hierarchy Process (AHP) method because it can help make decisions quickly and easily. [8].

The AHP method is a method used to rank the best decision alternative from several criteria that must be met or considered [9]. AHP is a structured method for organizing and analyzing complex decisions [10]. AHP is a decision-making method that considers qualitative and quantitative measures [11]. The AHP method has the working principle of simplifying a complex problem into a hierarchical form. The AHP hierarchy structure has three main components: objectives, criteria, and alternatives [12]. Previous research, namely research [13], concluded that calculations using a decision support system on JAMKESMAS acceptance with the AHP method were more efficient than manual calculations, and the accuracy of the data was close to perfect. Research [8] on decision support systems using the AHP and SAW methods in determining the location of ATMs can help make decisions quickly and easily. Research [14] used the AHP method to determine the location of the new BNI ATM, which obtained seven precise and strategic locations. Research [15] designed a program for implementing the AHP method in inventory control at PT. Sumber Rezeki Bersama and produce applications that can control inventory better and faster than manual calculations. This research will help the Indonesian Sharia Bank (BSI) of Jember Regency in determining the feasibility level of 10 BSI ATM locations that are already owned because BSI is a new sharia bank resulting from the merger of three Islamic banks so that it requires developers to maximize the feasibility of ATM locations. This study aimed to analyze the results of the ranking of the feasibility of BSI ATM locations using the AHP method.

2. RESEARCH METHOD

The data used in this study were primary and secondary. Primary data collection was obtained from interviews with 5 (five) BSI survey teams and Google Maps. Secondary data collection was obtained from the website of the Central Statistics Agency. The stages of data processing with the AHP method are carried out with the following steps:

a. Defining Problems and Creating Hierarchical Structures

The problem to be solved is determining the feasibility level of 10 BSI ATM locations. Based on the hierarchical structure component, the goal to be achieved is to determine the feasibility level of 10 BSI ATM locations with four criteria and ten alternatives which are presented in Table 1 below:

Table 1. Criteria and alternatives for determining the feasibility of a BSI ATM location

	Information	Symbols
Criteria	Distance from ATM to Crowd Center	X1
	Distance from ATM to Security Office	X2
	Total population	X3
	Number of non-BSI ATMs	X4
Alternative	ATM BSI Sudirman 1	Y1
	ATM BSI Sudirman 2	Y2
	ATM BSI KKAS UNMUH	Y3

Information	Symbols
ATM BSI UNMUH	Y4
ATM BSI A. Yani	Y5
ATM BSI Trunojoyo	Y6
ATM BSI Kalisat	Y7
ATM BSI Sukowono	Y8
ATM BSI Balung	Y9
ATM BSI Ambulu	Y10

The hierarchical structure of determining the feasibility level of 10 BSI ATM locations can be seen in Figure 1 below:

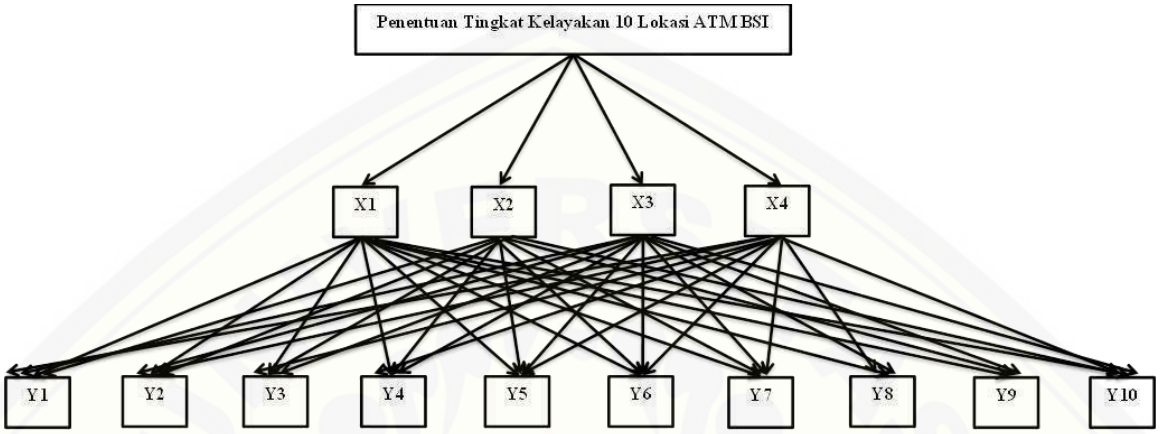

Figure 1. Hierarchical structure for determining the feasibility level of BSI ATM locations

b. Criteria Weight Calculation

The calculation of the criteria weight was carried out with the following steps:

1. Create a pairwise comparison matrix

Pairwise comparisons are carried out to compare one element's level with another. This pairwise comparison is transformed into a matrix form so the numerical calculation can be carried out. The pairwise comparison matrix assessment of each element uses a scale of 1 to 9, indicating the elements' level of importance [12]. The paired comparison rating scale can be seen in Table 2 below:

Table 2. Pairwise comparison rating scale

Interest Intensity	Definition	Explanation
1	Both elements are equally important	Two elements with equal influence in decision making
3	One element is slightly more important than the other	Experience and judgment suggest that one element is slightly more important than the others
5	One element is more important than the other	Experience and judgment suggest that one element plays a more significant role than the other elements
7	One element is more essential than the other elements	One essential and dominant element is seen in practice
9	One element is more essential than the other elements	Evidence in favor of one element is of the highest order
2, 4, 6, 8	The values between the two values of adjacent considerations. This value is given if there are two components between the two choices	
Reverse	If *i* activity gets one point compared to activity *j*, then *j* has the opposite value compared to *i*	

This pairwise comparison assessment is a group assessment, so subjective differences in values will be obtained. According to [16], the assessment subjectivity can be reduced by determining the final value using the average as in the following equation:

$$p_{ij} = \sqrt[n]{\prod_{k=1}^{n} p_{ij(k)}} \quad (1)$$

where,

p_{ij} : combined assessment of the *ij-th* element criteria/alternatives

$p_{ij(k)}$: the assessment of the *ij-th* element of the *k-th* respondent with *i,j*=1,2,3,…, *m* and k = $1,2,3,\dots,n$

n : number of respondents

2. Calculating weight value

The following equation was used to determine the normalization of the matrix as the first step in calculating the weight value:

$$N_{ij} = \frac{c_{ij}}{q_k} \quad (2)$$

where,

N_{ij} : the value of each element of the normalized matrix with $i, j = 1,2,\dots,n$

c_{ij} : the value of each element of the pairwise comparison matrix with $i, j = 1,2,\dots,n$

q_k : the total number of column values for each *k-th* criterion/alternative with $k = 1,2,\dots,n$.

Furthermore, from the normalization of the matrix, the weight value can be determined with the following equation:

$$w_k = \frac{\sum_{i=1}^{j} N_{ij}}{n} \quad (3)$$

where,

w_k : The weight value of *k-th* criterion/alternative with $k = 1,2,\dots,n$

N_{ij} : the value of each element of the normalized matrix with $i, j = 1,2,\dots,n$

n : many criteria/alternatives.

3. Checking hierarchy consistency

Check the consistency of the hierarchy by calculating the eigen values (λ) with the formula:

$$\lambda = \sum_{k=1}^{n}(q_k \times w_k) \quad (4)$$

where,

q_k : the total of column values for each *k-th* criterion/alternative with $k = 1,2,\dots,n$.

w_k : the weight value of *k-th* criterion/alternative with $k = 1,2,\dots,n$,

then, calculate the consistency index (**CI**) with the formula:

$$\boldsymbol{CI = \frac{\lambda - n}{n-1}} \quad (5)$$

where,

CI : consistency indeks

n : the number of criteria/alternatives

λ : eigen value,

then calculate the consistency ratio (**CR**) with the formula:

$$\boldsymbol{CR = \frac{CI}{IR}} \quad (6)$$

where,

CR : consistency ratio

IR : Index random consistency.

The consistency ratio (**CR**), which has a value less than or equal to 0.1, indicates the calculation results are correct (consistent). If the consistency ratio (**CR**) has a value above 0.1, then the calculation results are inconsistent. Therefore, it is recommended that decision-makers do a re-comparison on the pairwise comparison matrix [12]. The list of random consistency indices can be seen in Table 3, below:

Table 3. The list of consistency random index

Matrix Size ($n \times n$)	$IR\ Value$
1×1	0
2×2	0
3×3	0,58
4×4	0,90
5×5	1,12
6×6	1,24
7×7	1,32
8×8	1,41

Matrix Size ($n \times n$)	$IR\ Value$
9×9	1,45
10×10	1,49
11×11	1,51
12×12	1,48
13×13	1,56
14×14	1,57
15×15	1,59

c. Calculating Alternative Weights

The alternative weights were calculated in the same steps as step b. The first step was to create an alternative paired comparison matrix against the criteria, then calculate the weight values, and check the consistency of the hierarchy.

d. Determining Ranking Results

The ranking results can be determined from each criterion's weight and the alternatives obtained. The ranking results are obtained by adding up the multiplication of each criterion weight with each alternative weight. The best alternative is the alternative that has the highest value **[12]**.

3. RESULT AND DISCUSSION

The results in this study were calculated using the AHP method. The scoring for each element of the pairwise comparison matrix was obtained from the assessment of 5 BSI survey teams based on the pairwise comparison rating scale, as shown in Table 2. The weight values for all criteria and alternatives to the criteria were obtained from the normalized pairwise comparison matrix calculation. Then, the weight values were calculated. The results can be seen in Table 4, Table 5, Table 6, Table 7, and Table 8 below.

Table 4. Weight values for all criteria

Criteria	X1	X2	X3	X4	Total	Weight
X1	0,569	0,621	0,629	0,376	2,195	0,549
X2	0,148	0,161	0,146	0,325	0,780	0,195
X3	0,140	0,171	0,154	0,205	0,670	0,167
X4	0,143	0,047	0,071	0,094	0,355	0,089

In Table 4, the most critical priority criterion is the distance between the ATM and the center of the crowd (X1) because it has the most significant weight, which is 0.549. The following criteria with essential priorities are the criteria for the distance between ATMs and security offices (X2) with a weight of 0.195, the criteria for population (X3) with a weight of 0.167, and the criteria for the number of non-BSI ATMs (X4) with a weight of 0.089.

Table 5. Alternative weight value against criteria X1

X1	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Total	Weight
Y1	0,08	0,06	0,06	0,06	0,09	0,12	0,13	0,11	0,11	0,08	0,90	0,09
Y2	0,12	0,09	0,06	0,06	0,09	0,12	0,13	0,11	0,11	0,08	0,97	0,10
Y3	0,25	0,27	0,19	0,31	0,16	0,18	0,15	0,14	0,15	0,15	1,95	0,20
Y4	0,20	0,22	0,09	0,14	0,16	0,18	0,15	0,14	0,15	0,15	1,58	0,16
Y5	0,05	0,05	0,06	0,05	0,05	0,04	0,04	0,05	0,08	0,04	0,52	0,05
Y6	0,04	0,05	0,07	0,05	0,08	0,06	0,06	0,07	0,12	0,13	0,73	0,07
Y7	0,04	0,04	0,08	0,06	0,08	0,07	0,06	0,06	0,07	0,11	0,68	0,07
Y8	0,14	0,15	0,28	0,20	0,22	0,19	0,21	0,20	0,13	0,19	1,91	0,19
Y9	0,02	0,02	0,03	0,02	0,02	0,01	0,02	0,04	0,03	0,03	0,25	0,02
Y10	0,05	0,06	0,06	0,05	0,07	0,03	0,03	0,05	0,05	0,05	0,50	0,05

In Table 5, it can be seen that the BSI KKAS UNMUH ATM (Y3) has the most crucial priority in the criteria for the distance between the ATM and the center of the crowd (X1) because it has the most significant weight, which is 0.20.

Table 6. Alternative weight value against criteria X2

X2	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Total	Weight
Y1	0,10	0,20	0,13	0,12	0,12	0,10	0,11	0,12	0,06	0,09	1,15	0,11
Y2	0,04	0,08	0,13	0,12	0,12	0,10	0,11	0,12	0,06	0,09	0,97	0,10
Y3	0,03	0,03	0,04	0,11	0,04	0,02	0,03	0,08	0,06	0,07	0,51	0,05
Y4	0,03	0,03	0,02	0,04	0,04	0,02	0,03	0,08	0,06	0,07	0,41	0,04
Y5	0,09	0,07	0,12	0,11	0,10	0,22	0,11	0,12	0,07	0,11	1,12	0,11
Y6	0,08	0,06	0,14	0,13	0,04	0,08	0,12	0,10	0,07	0,09	0,91	0,09
Y7	0,08	0,07	0,12	0,11	0,08	0,06	0,09	0,08	0,13	0,08	0,91	0,09
Y8	0,03	0,03	0,02	0,02	0,03	0,03	0,04	0,04	0,04	0,06	0,36	0,04
Y9	0,27	0,22	0,12	0,11	0,24	0,19	0,10	0,14	0,15	0,11	1,64	0,16
Y10	0,24	0,20	0,15	0,13	0,20	0,19	0,25	0,14	0,31	0,22	2,02	0,20

In Table 6, the BSI Ambulu ATM (Y10) has the most critical priority in the criteria for the distance between the ATM and the security office (X2) because it has the most prominent weight value, which is 0.20.

Table 7. Alternative weight value against criteria X3

X3	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Total	Weight
Y1	0,09	0,05	0,09	0,05	0,12	0,16	0,16	0,13	0,13	0,08	1,05	0,10
Y2	0,17	0,10	0,09	0,05	0,12	0,16	0,16	0,13	0,13	0,08	1,18	0,12
Y3	0,26	0,30	0,26	0,43	0,23	0,19	0,17	0,14	0,15	0,21	2,32	0,23
Y4	0,26	0,30	0,10	0,16	0,23	0,19	0,17	0,14	0,15	0,21	1,90	0,19
Y5	0,07	0,09	0,12	0,08	0,11	0,16	0,15	0,10	0,14	0,13	1,13	0,11
Y6	0,03	0,04	0,08	0,05	0,04	0,06	0,09	0,10	0,10	0,09	0,67	0,07
Y7	0,03	0,03	0,08	0,05	0,04	0,03	0,05	0,12	0,12	0,08	0,63	0,06
Y8	0,03	0,04	0,09	0,05	0,05	0,03	0,02	0,05	0,04	0,04	0,43	0,04
Y9	0,03	0,03	0,07	0,04	0,03	0,02	0,02	0,05	0,04	0,06	0,38	0,04
Y10	0,03	0,04	0,04	0,03	0,03	0,02	0,02	0,04	0,02	0,03	0,30	0,03

In Table 7, it can be seen that the BSI KKAS UNMUH ATM (Y3) has the most important priority to the population criteria (X3) because it has the largest weight value, which is 0.23.

Table 8. Alternative weight value against criteria X4

X4	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Total	Weight
Y1	0,08	0,03	0,08	0,07	0,14	0,07	0,06	0,11	0,11	0,13	0,87	0,09
Y2	0,27	0,10	0,08	0,07	0,14	0,07	0,06	0,11	0,11	0,13	1,13	0,11
Y3	0,10	0,14	0,11	0,22	0,07	0,16	0,18	0,08	0,10	0,12	1,28	0,13
Y4	0,10	0,14	0,04	0,09	0,07	0,16	0,18	0,08	0,10	0,12	1,08	0,11
Y5	0,09	0,12	0,26	0,21	0,16	0,12	0,18	0,16	0,15	0,14	1,57	0,16
Y6	0,08	0,11	0,05	0,04	0,10	0,08	0,06	0,08	0,11	0,08	0,78	0,08
Y7	0,09	0,12	0,04	0,03	0,06	0,09	0,07	0,08	0,13	0,08	0,80	0,08
Y8	0,13	0,17	0,26	0,21	0,18	0,18	0,16	0,18	0,10	0,11	1,67	0,17
Y9	0,03	0,04	0,05	0,04	0,05	0,03	0,02	0,08	0,04	0,04	0,41	0,04
Y10	0,02	0,03	0,04	0,03	0,05	0,04	0,03	0,06	0,05	0,04	0,40	0,04

Table 8 shows that the Sukowono BSI ATM (Y8) has the most critical priority in the criteria for the number of non-BSI ATMs (X4) because it has the largest weight value, which is 0.17. The ranking results can be calculated by adding up the multiplication of the weights of each criterion with the weight of each alternative against the criteria, which can be seen in Table 9, below.

Table 9. Ranking results

Variables	ATM Locations	Values	Ranks
Y3	ATM BSI KKAS UNMUH	0,1674	1
Y4	ATM BSI UNMUH	0,1362	2
Y8	ATM BSI Sukowono	0,1339	3
Y2	ATM BSI Sudirman 2	0,1020	4
Y1	ATM BSI Sudirman 1	0,0968	5
Y5	ATM BSI A.Yani	0,0835	6
Y6	ATM BSI Trunojoyo	0,0760	7
Y10	ATM BSI Ambulu	0,0755	8
Y7	ATM BSI Kalisat	0,0730	9
Y9	ATM BSI Balung	0,0557	10

4. CONCLUSION

Based on the results and discussions described previously, it can be concluded that the ATM BSI KKAS UNMUH ranks first with a value of 0.1612. BSI KKAS UNMUH ATM is an ATM that has a location placement with the best feasibility level according to the four criteria chosen in this study because it has the most significant value among other alternatives. BSI Balung ATM is an ATM that ranks the lowest in the feasibility of placing a BSI ATM location with a value of 0.0557. An ATM that does not rank first does not mean that the placement of the location is not feasible, but the ATM does not meet the criteria based on the assessment given by the five survey teams in this study.

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Strategical Level Assessment of Bank Offices Location using Analytical Hierarchy Process Method

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Abstract. A strategic outlet/office location is essential in the business growth of a bank. This location determination includes the expected aspects of security, comfort, and convenience in transactions between the bank and the customer. Therefore we need a suitable method for determining the strategic location of the bank. This study aimed to determine the strategic level of the existing eight outlets/offices of Bank Syariah Indonesia in Jember Regency by considering the six predetermined criteria. This study uses the Analytical Hierarchy Process method to analyze stratified variables by considering the inconsistency tolerance limits of various criteria and determining alternatives. All important variables were given a numerical rating on the Saaty scale by respondents who were experts in their fields. Each variable will be compared with other variables to obtain a weight value, which determines the highest priority to the lowest for each variable. The results show that by using the Analytical Hierarchy Process method, the percentage of influence used is obtained from the distance between outlet and market, the distance between outlet and the center of government, the distance between outlet and the industrial area, the number of the Muslim residents, the number of residents over 40 years old, and the distance between outlet. and security office at 25.4%, 10.7%, 11.1%, 24.8%, 16.3%, 11.6% respectively. Based on the calculation results of the ranking value, the lowest alternative is BSI KCP KENCONG with a value of 0.044, and the highest alternative is BSI KCP JEMBER BALUNG with a value of 0.220. This value indicates the strategic level of the outlet/office by considering the weight of the 6 (six) criteria above. This strategic level is expected to be used as decision support for the bank in improving services to customers and prospective customers.

INTRODUCTION

An Islamic bank is a bank that, in its mobility, fund and capital role, is based on the principle of buying and selling and profit-sharing following Islamic sharia. Juridically, Islamic banks have an ideological and constitutional and operational foundation. This is evidenced by the enactment of the Sharia Banking Law on June 17, 2008. Since then, the achievements of Islamic financial institutions in Indonesia have increased yearly, as evidenced by the increasing number of Islamic banks formed. Fluctuating conditions due to COVID-19 do not necessarily affect Islamic banking. Islamic banking shows positive performance with the right and careful strategy, innovation, and risk mitigation. This performance is evidenced by the State-Owned Enterprises (BUMN) merging of three state-owned banks, namely PT. Bank Syariah Mandiri, PT Bank Rakyat Indonesia, and PT Bank BNI Syariah, later called PT Bank Syariah Indonesia (BSI) Tbk. to maximize the potential of Islamic banking in the future. The merger of the three state-owned banks is intended to increase assets automatically and become more trusted by the public as one of today's financial services. One of the services that Islamic banks can provide is the location of an affordable and

strategic bank office. The bank's location is a place for trading banking products and a banking control centre for customers and prospective customers to improve the economic level of the community and the banking world. The selection of the right location is undoubtedly essential, considering that the establishment of a bank is intended to provide maximum service and facilitate promotions that banks will carry out to give a good impression in order to increase the intensity of transactions carried out by the public so that the selection of a strategic location is significant in all aspects, such as comfort, convenience and of course security.

Unfortunately, the bank's selection of this location is subjectively made with several variables, giving an unstructured impression. So we need a method that can simplify complex problems with several unstructured and dynamic variables into parts and arrange them in a hierarchical structure to make them easier to understand. The Analytical Hierarchy Process is one of the decision support methods developed by Saaty that uses several variables in a multilevel analysis process. This analysis is carried out by assigning a scale value of 1 (one) to 9 (Nine) and performing pairwise comparisons of the existing criteria and alternatives. The Analytical Hierarchy Process considers logical consistency values below 0.1. If it exceeds 0.1, the results obtained are considered less than optimal and representative, so it is necessary to re-comparison. Based on the explanation above, the Analytical Hierarchy Process is very useful in assessing the strategic location of Bank Syariah Indonesia offices. With the hope that it can help determine the strategic level of the location of Bank Syariah Indonesia outlets in Jember Regency. Because strategic bank offices are very influential in bank services for customers and prospective customers.

METHODOLOGY

The Analytical Hierarchy Process is often used as a problem-solving method because the hierarchical structure as a consequence is chosen for the deepest sub-criteria. The basic principles that must be met in this method include decomposition, pairwise comparisons, priority synthesis, and logical consistency. These four basic principles are contained in the following steps of the Analytical Hierarchy Process method bellow.

Step 1: Defining the problem, determining criteria and alternatives

The problem to be solved is the strategic level of the BSI Bank office location. Possible criteria that can affect the level of strategic office location have been considered based on the existing literature. The related criteria and sub-criteria have been selected with the help of 5 experts in selecting bank office locations according to their suggestions. The three main criteria are distance, population and security. In comparison, the alternative is in the form of a distribution of 8 BSI bank offices in Jember Regency. The criteria and alternatives used in this study are described in this following TABLE 1.

TABLE 1. The criteria and alternative that use for assessment strategic level outlets of BSI

Criteria/Alternative	Notation	Subcriteria/Alternative
Distance	C1	Distance between outlet and markets
	C2	Distance between outlet and center goverments
	C3	Distance between outlet and industrial area
Number of people	C4	Number of Muslims residents
	C5	Number of residents over 40 years old
Security level	C6	Distance between outlet and security office
BSI Office name	A1	BSI KC JEMBER A. YANI
	A2	BSI KCP AMBULU
	A3	BSI KCP KENCONG
	A4	BSI KC JEMBER TRUNOJOYO
	A5	BSI KC JEMBER SUDIRMAN
	A6	BSI KCP JEMBER BALUNG
	A7	BSI KK JEMBER UNMUH
	A8	BSI KK KALISAT

Step 2: Making a pairwise comparison matrix

This pairwise comparison is transformed into a matrix so the numerical calculation can be carried out. The pairwise comparison matrix is filled in using numbers to represent the relative importance of an element with other elements. The paired comparison rating scale can be seen in the following table.

TABLE 2. Importance level comparison scale

Notation	Subcriteria/Alternative
1	Both elements are equally important
3	One element is slightly more important than the others
5	An element has a strong level of importance compared to other elements
7	An element shows a very strong level of importance compared to other elements
9	An element shows an absolute higher level of importance than the other elements
2,4,6,8	Middle values between two side-by-side opinions
opposite	If activity i gets one point compared to activity j, then j has the opposite value compared to i.

Step 3: Calculation of the weight of criteria and alternatives

This calculation uses the normalized matrix eigenvector values, which will determine the priority of the elements. This step starts with the sum of the values of each column in the matrix. Then, divide each value from the column by the corresponding column total to get the normalized matrix. Then, add up the values of each row and then divide by the number of criteria to obtain the priority weight of the criteria.

Step 4: Consistency checking

Consistency needs to be considered to determine whether the consistency between the elements assessed is correct and has optimal results. The consistency tolerance threshold is 0.1. If it is more than 0.1, then the pairwise comparison matrix needs to be improved again. The formula to check consistency is given bellow.

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{IR}} \tag{1}$$

Step 5: Global priority

This step is the last step to find out the ranking value of each alternative. The way to get the ranking value is by multiplying the criterion weight and the alternative weights for each criterion. Global priority formula in this research is given bellow.

$$Z_j = \left(X_1 \times Y_j C_1\right) + \left(X_2 \times Y_j C_2\right) + \ldots + \left(X_6 \times Y_j C_6\right) \tag{2}$$

RESULTS AND DISCUSSION

Assessment of the strategic level of bank office locations is essential. Because the strategic location will affect the performance of banking services to customers and prospective customers. In this research, the strategic assessment of bank office locations was carried out using the Analytical Hierarchy Process method. The results obtained are weighted criteria and alternatives to calculate the ranking value of each alternative. The main criteria used are distance, population, and security. At the same time, the sub-criteria used include the distance between outlets and market, distance between outlets and center of government, distance between outlets and industrial areas, number of Muslim residents, number of residents aged over 40 years, and distance between outlets and security office.

TABLE 3. Weight of each criterion

Criteria	C1	C2	C3	C4	C5	C6	weight
C1	0.246	0.339	0.240	0.192	0.307	0.203	0.254
C2	0.062	0.086	0.137	0.067	0.211	0.080	0.107
C3	0.118	0.072	0.115	0.178	0.066	0.120	0.111
C4	0.328	0.326	0.165	0.255	0.232	0.181	0.248
C5	0.107	0.054	0.233	0.147	0.133	0.302	0.163
C6	0.139	0.123	0.110	0.161	0.050	0.114	0.116

TABLE 2 above shows that the respondents in determining the strategic location of BSI bank outlets prioritize the criteria for the distance between outlet and market (C1) as the most influential criterion. Followed by the number of Muslim residents (C4), the number of residents aged over 40 years (C5), the distance between outlet and security office (C6), the distance between outlet and industrial area (C3), and the last one is the distance between outlet and center of government (C2). The weighting is supported by the consistency calculation, which shows a value of 0.069 which means that the weighting results of these criteria are optimal.

TABLE 4. Weight of alternative for criteria C1

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	weight
A1	0.033	0.017	0.018	0.020	0.058	0.044	0.097	0.036	0.040
A2	0.078	0.039	0.025	0.023	0.120	0.047	0.086	0.038	0.057
A3	0.110	0.093	0.060	0.033	0.086	0.073	0.124	0.052	0.079
A4	0.218	0.226	0.236	0.132	0.214	0.102	0.186	0.133	0.181
A5	0.019	0.011	0.023	0.021	0.034	0.053	0.119	0.038	0.040
A6	0.271	0.306	0.296	0.470	0.228	0.363	0.186	0.380	0.312
A7	0.008	0.010	0.011	0.016	0.006	0.043	0.022	0.035	0.019
A8	0.264	0.298	0.331	0.286	0.255	0.275	0.181	0.288	0.272

TABLE 4 above shows that the alternative that has the highest weight in criteria distance between outlets and market (C1) is BSI KCP JEMBER BALUNG (A6) with a value of 0.312.

TABLE 5. Weight of alternative for criteria C2

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	weight
A1	0.026	0.024	0.011	0.011	0.009	0.027	0.026	0.057	0.024
A2	0.199	0.182	0.249	0.276	0.280	0.213	0.211	0.142	0.219
A3	0.115	0.035	0.048	0.024	0.024	0.160	0.158	0.061	0.078
A4	0.199	0.054	0.163	0.082	0.183	0.213	0.211	0.071	0.147
A5	0.189	0.044	0.134	0.030	0.068	0.106	0.105	0.081	0.095
A6	0.026	0.023	0.008	0.010	0.017	0.027	0.026	0.056	0.024
A7	0.026	0.023	0.008	0.010	0.017	0.027	0.026	0.053	0.024
A8	0.220	0.614	0.378	0.556	0.402	0.228	0.237	0.479	0.389

TABLE 5 above shows that the alternative that has the highest weight in criteria distance between outlets and center goverments (C2) is BSI KK KALISAT (A8) with a value of 0.389.

TABLE 6. Weight of alternative for criteria C3

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	weight
A1	0.034	0.041	0.083	0.022	0.027	0.022	0.028	0.040	0.037
A2	0.223	0.271	0.167	0.233	0.497	0.153	0.195	0.243	0.248
A3	0.010	0.040	0.025	0.016	0.023	0.012	0.024	0.021	0.021
A4	0.087	0.065	0.087	0.056	0.043	0.028	0.058	0.044	0.058
A5	0.244	0.106	0.207	0.253	0.195	0.194	0.390	0.295	0.236
A6	0.085	0.098	0.117	0.112	0.055	0.055	0.027	0.037	0.073
A7	0.237	0.271	0.202	0.188	0.097	0.396	0.195	0.224	0.226
A8	0.080	0.106	0.112	0.121	0.063	0.141	0.083	0.095	0.100

TABLE 6 above shows that the alternative that has the highest weight in criteria distance between outlets and industrial area (C3) is BSI KCP AMBULU (A2) with a value of 0.248.

TABLE 7. Weight of alternative for criteria C4

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	weight
A1	0.053	0.030	0.090	0.046	0.035	0.048	0.057	0.169	0.066
A2	0.143	0.081	0.165	0.255	0.231	0.053	0.071	0.174	0.147
A3	0.021	0.018	0.036	0.012	0.016	0.035	0.067	0.069	0.034
A4	0.053	0.015	0.134	0.046	0.115	0.043	0.053	0.084	0.068
A5	0.080	0.019	0.117	0.021	0.053	0.055	0.070	0.095	0.064
A6	0.219	0.304	0.200	0.209	0.188	0.196	0.169	0.147	0.204
A7	0.421	0.520	0.243	0.395	0.346	0.531	0.455	0.233	0.393
A8	0.009	0.014	0.015	0.016	0.016	0.039	0.057	0.029	0.025

TABLE 7 above shows that the alternative that has the highest weight in criteria number of Muslim residents (C4) is BSI KK JEMBER UNMUH (A7) with a value of 0.393.

TABLE 8. Weight of alternative for criteria C5

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	weight
A1	0.055	0.035	0.025	0.084	0.030	0.047	0.078	0.146	0.062
A2	0.170	0.108	0.138	0.209	0.201	0.067	0.090	0.146	0.141
A3	0.129	0.046	0.059	0.029	0.032	0.050	0.081	0.110	0.067
A4	0.055	0.043	0.172	0.084	0.140	0.065	0.099	0.110	0.096
A5	0.129	0.038	0.127	0.042	0.070	0.065	0.079	0.110	0.083
A6	0.195	0.268	0.197	0.214	0.179	0.167	0.124	0.137	0.185
A7	0.248	0.425	0.256	0.299	0.314	0.477	0.354	0.190	0.321
A8	0.019	0.038	0.027	0.039	0.032	0.062	0.095	0.051	0.045

TABLE 8 above shows that the alternative that has the highest weight in criteria number residents aged over 40 years (C5) is BSI KK JEMBER UNMUH (A7) with a value of 0.321.

TABLE 9. Weight of alternative for criteria C6

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	weight
A1	0.044	0.054	0.106	0.118	0.106	0.028	0.090	0.031	0.072
A2	0.283	0.344	0.231	0.167	0.181	0.337	0.198	0.483	0.278
A3	0.020	0.072	0.049	0.116	0.083	0.028	0.118	0.042	0.066
A4	0.011	0.062	0.012	0.030	0.013	0.022	0.030	0.032	0.027
A5	0.016	0.072	0.022	0.087	0.038	0.026	0.071	0.029	0.045
A6	0.264	0.172	0.289	0.226	0.244	0.169	0.223	0.111	0.212
A7	0.015	0.052	0.012	0.030	0.016	0.023	0.030	0.030	0.026
A8	0.346	0.172	0.278	0.226	0.319	0.366	0.240	0.241	0.274

TABLE 9 above shows that the alternative that has the highest weight in criteria distance between outlets and security office (C6) is BSI KCP AMBULU (A2) with a value of 0.278. The research results also show the strategic level of bank office locations after calculating the overall global priorities by using Equation 2, the results are shown in TABEL 10 below.

TABLE 10. Alternative ranking results

Alternative	Bank Office Name	Score	Rangking
A1	BSI KC JEMBER A. YANI	0.052	8
A2	BSI KCP AMBULU	0.157	4
A3	BSI KCP KENCONG	0.058	7
A4	BSI KC JEMBER TRUNOJOYO	0.104	5
A5	BSI KC JEMBER SUDIRMAN	0.081	6
A6	BSI KCP JEMBER BALUNG	0.196	1
A7	BSI KK JEMBER UNMUH	0.185	2
A8	BSI KK KALISAT	0.167	3

CONCLUSION

The results show that using the Analytical Hierarchy Process method can provide a ranking of 8 (eight) alternatives by considering 6 (six) strategic criteria for the location of Bank Syariah Indonesia outlets. The percentage of influence from the criteria used are the distance between outlet and market, the distance between outlet and the center of government, the distance between outlet and the industrial area, the number of the Muslim residents, the number of residents over 40 years old, and the distance between outlet. and security office at 25.4%, 10.7%, 11.1. %, 24.8%, 16.3%, 11.6% respectively. The alternative with the highest ranking value was KCP JEMBER BALUNG, followed by KK JEMBER UNMUH, KK KALISAT, KCP AMBULU, KC JEMBER TRUNOJOYO, KC JEMBER SUDIRMAN, KCP KENCONG, and the lowest was KC JEMBER A. YANI. This ranking value is expected to support the decision of the banking sector to further develop services for customers and prospective customers in that location.

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Application of *Multiple Objective Programming Method* for Optimization and Sensitivity Analysis of Furniture Production

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Abstract. The *Multiple Objective Programming method* allows two or more general approaches to achieve conflicting goals, which are indicated by positive and negative deviations. This method will be applied to optimize furniture production, a case study on a furniture company in Kebumen. Furthermore, the optimal value will be analyzed for sensitivity when there are some limited resources. The three decision variables used are a 4-door wardrobe, a 3-door wardrobe, and a set of chairs, while the simulation program uses *an add-in excel solver* in *Microsoft Excel software*. The calculations using the *multiple objective programming methods* show an increase in the production of chair sets. They are also proven to reduce raw material, labor, and production costs. The sensitivity analysis results from this study confirm that the *shadow price* of the 3-door wardrobe is the most sensitive to changes.

INTRODUCTION

Wooden furniture is one of the pieces of furniture owned by households in Indonesia. Each region in Indonesia has its characteristics or uniqueness in designing wooden furniture patterns. This uniqueness makes wooden furniture much in demand by domestic and foreign consumers. However, several problems occur in the furniture industry; for example, consumers prefer minimalist designs, lightweight materials, and low prices. Since the beginning of 2020, the furniture industry in Indonesia has experienced ups and downs due to the current COVID-19 pandemic.

Optimization is a process to maximize profits and minimize costs or constraints. Constraints that usually occur in optimization problems are the company's lack of maximum profit, losses experienced in large numbers, unstable production quantities, and so on. Solving the problems of these constraints can be done with linear programming. Linear programming is a solution to the problem of allocating limited resources. A standard linear program has only one objective to be optimized, for example, to maximize or minimize.

After completing the optimization case, there may be factors that can cause uncertainty, affecting the sensitivity level of the business. Thus, further analysis is needed to process the uncertainty that occurs so that the results remain optimal, called sensitivity analysis [9]. Sensitivity analysis is essential to know to what extent the coefficients of the objective function and the value of the constraint function may change without affecting the optimality of the effort. [2] conducted a sensitivity analysis study to optimize the profit of clothing production with the simplex method. This research proved that the profits increased rapidly.

Production planning will be carried out to optimize this research using *multiple objective programming methods* or *goal programming*. The concept applied in this method is that there are two general approaches to examining conflicting goals, namely the existence of negative and positive deviations that may occur when achieving goals [4]. G*oal programming* causes this method to be used to optimize conflicting goals at the same time [7]. Research conducted by [1] proves that the *multiple objective programming methods* can optimize the planting pattern of mustard

greens and cucumbers on dry land. In a study by [12] on reducing nutrient variation. It was found that the *multiple objective programming models* provide the best compromise solution to satisfy many decision-makers when a *trade-off* between ration costs and minimum variation of protein and methionine. Several other studies related to goal programming have been written by [3,5,8,10].

The problem in the furniture production process at one of the furniture companies in Kebumen is the desire to obtain maximum profit but the availability of minimum costs in the production process. The *multiple objective programming methods* were chosen to solve this problem to achieve an optimal solution and determine the sensitivity level of resource changes by conducting sensitivity analysis.

METHODOLOGY

Linear programming has three essential components, namely: (1) decision variables to determine the constraints that need to be found; (2) objective function or objective function to obtain variables that need to be minimized or maximized; and (3) problems that must be solved. The primary method of this research is linear programming, which is mathematically formulated as follows [11]

Maximize or minimize

$$Z = \sum_{j=1}^{n} c_j x_j \tag{1}$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j (\leq, =, \geq) b_i \, , (\, i = 1,2 \ldots m \; and \; j = 1,2, \ldots , n) \tag{2}$$

where

x_j = the decision j variable.
Z = function (maximum or minimum).
c_j = objective function coefficient per unit x_j.
a_{ij} = the number of th resources i used for each x_j.
b_i = the number of available resources i to be allocated to each activity.

It was developed into multiple objective or goal programming based on linear programming [6]. The general model of multiple objective programming is as follows:

a. Objective Function
Minimize

$$Z = \sum_{p=1}^{M} {d_p}^{-} - {d_p}^{+} \tag{3}$$

where

${d_p}^{+}$= p-th top deviation
${d_p}^{-}$= p-th bottom deviation

b. Goal Constraint

$$b_p = \sum_{j=1}^{n} a_{pj} x_j + {d_p}^{-} - {d_p}^{+} \, , (\, p = 1,2 \ldots M \; and \; j = 1,2, \ldots , n) \tag{4}$$

where

a_{pj} = coefficient associated with x_j for the goal p-th
x_j = decision variable to-j
b_p = goal value to-p

c. Non-negative constraints

$$x_j, d_p^-, d_p^+ \geq 0 \quad (5)$$

From the general model in Equation (3) - Equation (5) can be seen that d_p^+ is a subtraction of d_p^-; this is because $d_p^-$and d_p^+ is the deviation variable whose job is to accommodate the deviation on the left side, so that it is the same as the right side so that d_p^-+ d_p^+= 0.

In linear programming, the model's parameters (input data) can change within certain limits without causing the optimal solution to change, called sensitivity analysis. Sensitivity analysis can ascertain the impact of this uncertainty on the quality of the optimal solution. Sensitivity analysis could do in two ways, namely, by making changes to the objective function and changing the constant of the right-hand side of the constraint function [11]. From the changes made, a dual value (shadow price) will be obtained. A dual value *(shadow price) will obtain* from the changes made. A sensitivity analysis can be carried out in the following ways:

1. Change in the coefficient of the objective function

   To obtain the change interval for the objective coefficient using the equation

$$(c_j - z_j) - a_{ij}\Delta c_j + \Delta c_j, (\, i = 1,2 \ldots m \; and \; j = 1,2, \ldots, n) \quad (6)$$

   where

   c_j = coefficient per unit of activity j

   a_{ij} = number of resources i used for each x_j

   The objective function's coefficients can make changes per the allowable change interval.

2. Change in the constant of the right-hand side of the constraint function

   To obtain the change interval for the right-hand side of the constraint function using the ratio approach:

$$\frac{b_i}{a_{ij}}, (\, i = 1,2 \ldots m \; and \; j = 1,2, \ldots, n) \quad (7)$$

   where

   b_i = the number of resources i

   a_{ij} = number of resources i used for each x_j

   After the ratio results are obtained, the constraint function's right side can make changes per the allowable change interval.

RESULTS AND DISCUSSION

The data in this paper were obtained from furniture business owners in Kebumen. The decision variables in this study were a 4-door wardrobe (x_1), a 3-door wardrobe (x_2), and a set of chairs (x_3). The model formation consists of constraint function modeling and objective function modeling. The first is modeling the constraint function based on each goal to be achieved. The constraint function modeling is divided into two parts arranged in two tables. Table 1 is a table that contains the limits that are maximized, including production output (units), production value (rupiah/unit), and profit (rupiah/unit). Meanwhile, Table 2 contains the constraints that were minimized, including raw material costs (Rp/unit), labor costs (Rp/person), and production costs (Rp/unit).

TABLE 1. Constraints to be maximized for each item

Types of goods	Production result (Units)	Production Value (Rupiah/unit)	Profit (Rupiah/unit)
4 door wardrobe (x_1)	8	5.250	1,350
3 door wardrobe (x_2)	10	4.850	1,250
Chair set (x_3)	6	5.550	1.450
Total	**-**	**134,400**	**35,000**

TABLE 2. Constraints to be minimized for each item

Types of goods	Cost of Raw Materials (Rupiah/unit)	Labor Costs (Rupiah/person)	Production cost (Rupiah/unit)
4 door wardrobe (x_1)	2,250	400	3.700
3 door wardrobe (x_2)	2.150	200	3,200
Chair set (x_3)	2,500	300	4,000
Availability Cost	**64,000**	**9800**	**110,000**

Based on the results of production, production value, and profit, the objective function constraints can be formulated, which will be maximized for production results, production values, and profits as in Table 3.

TABLE 3. Formulation of the constraint function to be maximized

Constraint	Constraint Function
4 door wardrobe (x_1)	$x_1 + d_1^- - d_1^+ = 8$
3 door wardrobe (x_2)	$x_2 + d_2^- - d_2^+ = 10$
Chair set (x_3)	$x_3 + d_3^- - d_3^+ = 6$
Production Value	$5250x_1 + 4850x_2 + 5500x_3 + d_4^- - d_4^+ = 134400$
Profit	$1350x_1 + 1250x_2 + 1450x_3 + d_5^- - d_5^+ = 35000$

Table 4 shows the objective function constraint formulas for raw material, labor, and production costs.

TABLE 4. Formulation of the constraint function to be minimized

Target Constraint	Constraint Function
Raw material cost	$2250x_1 + 2150x_2 + 2500x_3 + d_6^- - d_6^+ = 64000$
Labor cost	$400x_1 + 200x_2 + 300x_3 + d_7^- - d_7^+ = 9800$
Production cost	$3700x_1 + 3200x_2 + 4000x_3 + d_8^- - d_8^+ = 110000$

In the multiple objective programming methods, the thing that needs to be done to achieve the goal is to minimize the number of deviations. The objective function modeling that has been given priority factors is as follows:

Minimize

$$Z = x_1 + x_2 + x_3 + P_1 d_1^- + P_2 d_2^- + P_3 d_3^- + P_4 d_4^- + P_5 d_5^- + P_6 d_6^+ + P_7 d_7^+ + P_8 d_8^+ \quad (8)$$

subject to

$$\begin{gathered} x_1 + d_1^- - d_1^+ = 8 \\ x_2 + d_2^- - d_2^+ = 10 \\ x_3 + d_3^- - d_3^+ = 6 \\ 5250x_1 + 4850x_2 + 5500x_3 + d_4^- - d_4^+ = 134400 \\ 1350x_1 + 1250x_2 + 1450x_3 + d_5^- - d_5^+ = 35000 \\ 2250x_1 + 2150x_2 + 2500x_3 + d_6^- - d_6^+ = 64000 \\ 400x_1 + 200x_2 + 300x_3 + d_7^- - d_7^+ = 9800 \\ 3700x_1 + 3200x_2 + 4000x_3 + d_8^- - d_8^+ = 110000 \end{gathered} \quad (9)$$

Minimizing Z is to minimize deviations or deviations from the shortage of 4-door wardrobe production (d_1^-), shortage of 3-door wardrobe production(d_2^-), shortage of chair set production (d_3^-), shortage of production value (d_4^-), shortage of profit (d_5^-), excess of raw material costs (d_6^+), excess of labor costs (d_7^+), excess production costs (d_8^+) to achieve optimal solutions.

The results obtained in this study indicate that furniture production has increased or is optimal in the production of chair sets. The slack value of 0 (zero) proves that the value for each objective function is met. First, the optimization results obtained a value of Z= 26 units with the production results obtained for a 4-door wardrobe (x_1) of eight units, d_1^-= 0, d_1^+= 0, meaning that the optimization of a 4-door wardrobe is the same as expected. Second, the production result for the 3-door wardrobe (x_2) is ten units, d_2^-= 0, d_2^+= 0, so the optimization for the 3-door wardrobe is the same as expected. Third, the production result for the set of chairs (x_3) is eight units with d_3^-= 0, d_3^+= 2, meaning that there is an increase of two units in the set of chairs. The total value of production in this study was Rp 135.283.000 with

x_1= 42,000,000 , x_2= 48,500,000 , x_3= 44,782,800 , d_4^-= 0, d_4^+= 882,759. The deviations that occur indicate an increase in the production value, meaning that the results obtained exceed the expected. Furthermore, the profit obtained is Rp. 35,000,000 with x_1= 10,800,000 , x_2= 12,500,000 , x_3= 11.700.000 , d_5^-= 0, d_5^+= 0. So, it can be interpreted that the profit obtained after optimization is the same as expected.

In the constraints that want to be minimized, the raw material costs in this optimization are Rp59,672,400 with x_1= 18,000,000 , x_2= 21,500,000 , x_3= 20,172,400 , d_6^-= 4,327,590 , d_6^+= 0. The labor costs that need to be incurred are equal to Rp 7,620,690 with x_1= 3,200,000 , x_2= 2,000,000 , x_3= 2,420,690 , d_7^-= 2.179,310 , d_6^+= 0. Finally, the production costs that need to be spent to do production are Rp. 93,875,900 with x_1= 29,600,000 , x_2= 32,000,000 , x_3= 32,275,900 , d_6^-= 16,124,100 , d_6^+= 0. The deviation that occurs in the cost of raw materials, labor costs, and production costs indicate that the costs that need to be incurred can be minimized from the availability of costs.

The optimization results of each unit prove that the eight factors to be achieved can be satisfied. Table 5 is a breakdown of the value of the decision variables based on the optimization results.

TABLE 5. Value of decision variables based on optimization results

Optimization Results	RHS Value	Results	Status
Maximizing the production of 4-door wardrobe	8	8	satisfied
Maximize production of 3-door wardrobe	10	10	satisfied
Maximize the production of chair sets	6	8	satisfied
Maximizing production value	134.400.000	135.283,000 _	satisfied
Maximize profit	35.000.000	35.000 000	satisfied
Minimize raw material costs	64.000.000	59.672.400	satisfied
Minimize labor costs	9.800.000	7.620.690	satisfied
Minimize production costs	110.000.000	93.875.900	satisfied

The sensitivity analysis results show the extent to which can be changed in this study. The sensitivity value obtained for each constraint is the range where the dual value (*shadow price*) applies. The acquisition of the *shadow price* in detail can be seen in Table 6 as follows:

TABLE 6. Dual value (*shadow price*) based on optimization results

Optimization Results	*Shadow Price*	Information
4 door wardrobe	0.068965517	sensitive
3 door wardrobe	0.137931034	Most sensitive
Chair Set	$1.7641\times e^{-16}$	Not enough sensitive
Production Value	0	Not sensitive
Profit	0.000689655	Less sensitive
Raw Material Cost	0	Not sensitive
Labor costs	0	Not sensitive
Production cost	0	Not sensitive

The most sensitive shadow price is only on the production target constraint of a 3-door wardrobe with a shadow price of 0.137931034. The results of the shadow price mean that the constraint for the 3-door wardrobe is the most sensitive than the other seven constraints because if an addition is made to the unit, it will experience a greater increase than increasing in other units.

CONCLUSION

From the research results, *multiple objective programming methods* can apply to optimize furniture production at one of the furniture companies in Kebumen. This study obtained a value of $Z = 26$ units with increased production results in a set of chairs by two units. *Multiple objective programming* is also proven to minimize the cost of raw materials, labor, and production costs from the availability of costs. With the shadow price of the sensitivity analysis that has been carried out, it can conclude that the 3-door wardrobe is the most sensitive compared to the other seven target constraints.

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Recommendations for Bank Savings Using the Fuzzy Analytical Hierarchy Process Method

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ABSTRACT

Each bank has different savings product offering and has its own advantages. This research will help prospective customers in choosing savings from 5 state banks that best fit the desired criteria using the Fuzzy Analytical Hierarchy Process (F-AHP) method. The Fuzzy AHP method is an AHP method that is processed based on the fuzzy concept approach. This study aim to obtain the results of the application of the Fuzzy AHP method in the form of rankings for the selection of savings from 5 state-owned banks in Jember Regency. From this study, the results were obtained that BTN Juara are most recommended for students in choosing savings product in accordance with the assessment of the 5 criteria as follows administrative costs, interest rates, facilities, services, and the number of branch offices of the bank.

Keywords: Bank; Savings; Decision Support System; AHP; Fuzzy AHP

INTRODUCTION

Savings can help ensure financial stability if something unexpected occurs in the future. Nowadays, most people keep their savings in banks. Each bank has its own offers and advantages, as well as savings products offered to potential customers. The difference in the criteria of each bank is considered for prospective customers in choosing savings from the various available banks. Building a Decision Support System can solve problems related to the selection of bank savings for customers (SPK). The Analytical Hierarchy Process (AHP) method is one that can be used to support decisions.

The AHP method or Analytical Hierarchy Process is a decision support model that decomposes complex multi-factor or multi-criteria problems into a hierarchy. However, AHP has difficulty in dealing with subjective judgments and uncertainties. Therefore, fuzzy AHP is used to overcome AHP's inability to handle linguistic variables [1]. the approach taken in the AHP fuzzy procedure is to fuzzify on the AHP scale to obtain a new scale called the AHP fuzzy scale [2].

Research by Shega et al (2012), presents that the fuzzy AHP method can be used in determining priority weights for each criterion that forms the basis for appropriate analysis in the multi-criteria decision-making process [2]. Igon et al (2014) in their research on the design of decision support systems with the fuzzy AHP method can help in producing more objective decisions in the form of a list of eligibility ratings of

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borrowers [11]. Research by Farid and Suhendar (2019) regarding supplier selection for PT. XYZ produces an alternative decision that is selected is the PT that has the highest priority weight value [10]. Akbar (2020) in his research on teacher performance appraisal concluded that, fuzzy AHP has a good level of accuracy so that it helps the decision-making process quickly [9].

METHODS

Banking

Banks are important financial institutions in the economy of a country. Bank regulates the payment system and implements government policies in the field of finance. Savings is a deposit of money at a bank whose withdrawal can be made under certain conditions. Withdrawal of savings can be through withdrawal slips at banks, passbooks, and ATMs. Withdrawal of money on the account can be made at any time [6].

Sistem Pendukung Keputusan

A system is a collection of elements within the scope of a problem of mutual integrity that are directed at one definite goal. The system is divided into 3 parts, namely input, process, and output [3].

Logika Fuzzy

Fuzzy logic is a method of processing data based on human perception and inference using a series of membership sets. The range of membership values on the fuzzy set lies at 0 to 1. The fuzzy set has two variables, namely numerical and linguistic. Linguistics is expressed by naming a group according to the use of natural language, such as high, low, old, young and others. Numeric is a number that expresses a value to indicate the size of variables such as 5, 18, 42 and others [4].

Metode Analytical Hierarchy Process (AHP)

AHP is a method used to sort alternative decisions by choosing the best decision alternative when the decision maker has different criteria. The AHP method facilitates the selection of the best alternatives according to the decision criteria and provides a score for each alternative decision based on the feasibility of each alternative [5].

Fuzzy Analytical Hierarchy Process (AHP)

The degree of fuzzy membership of AHP is determined using the rules of the triangular fuzzy function or Triangular Fuzzy Number (TFN) compiled based on linguistic sets. Thus, the numbers at the level of intensity of importance in the AHP are translated into the set of the TFN scale [7]. Each membership function is defined in three parameters namely *l, m,* and *u* where *l* (lower) is the lowest probability value, *m* (medium) is the middle probability value, and *u* (upper) is the highest probability value of the decision interval.

Table 1. Triangular Fuzzy Number Scale

Definition	Saaty Scale	TFN	Saaty Scale Inverse
Equally important	1	(1,1,1)	(1,1,1)
A little more important	3	(1, 3/2, 2)	(1/2, 2/3, 1)
More important	5	(2, 5/2, 3)	(1/3, 2/5, 1/2)

Definition	Saaty Scale	TFN	Saaty Scale Inverse
Very important	7	(3, 7/2, 4)	(1/4, 2/7, 1/3)
Absolutely more important	9	(4, 9/2, 9/2)	(2/9, 2/9, 1/4)
Adjacent values	2	(1/2, 1, 3/2)	(2/3, 1, 2)
	4	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
	6	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
	8	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

The stages of solving the problem using the FUZZY AHP method are as follows [8]

Step 1. Compile and create a hierarchical structure of the problems to be solved.

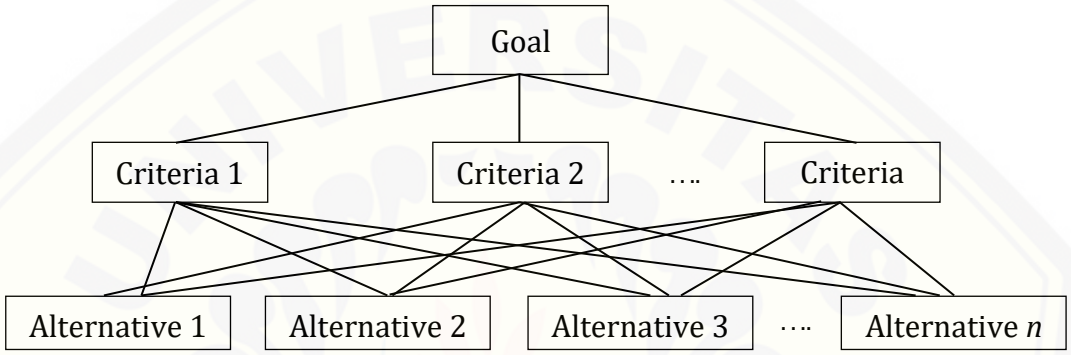

Figure 1. The hierarchical structure of the problem

Step 2. Determines the matrix of pairwise comparisons between criteria and alternatives.

Step 3. Change the weight of the pairwise comparison assessment into the TFN numbers and change the linguistic variables in the form of fuzzy numbers.

Step 4. Determining the priority fuzzy synthesis values (S_i) for each criterion and alternative according to equation (1)

$$S_i = \sum_{j=1}^{n} M_{g_i}^{j} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{n} M_{g_i}^{j} \right)^{-1} \quad (1)$$

where

$$\sum_{j=1}^{n} M_{g_i}^{j} = \left(\sum_{j=1}^{n} l_j , \sum_{j=1}^{n} m_j , \sum_{j=1}^{n} u_j \right) \quad (2)$$

while

$$\left(\sum_{i=1}^{n} \sum_{j=1}^{n} M_{g_i}^{j} \right)^{-1} = \frac{1}{\sum_{i=1}^{n} u_i , \sum_{i=1}^{n} m_i , \sum_{i=1}^{n} l_i} \quad (3)$$

Information:

M = TFN (Triangular Fuzzy Number) number

n = number of criteria

j = index on matrix columns

i = index on the matrix row

g = parameters (l, m, u)

$\sum_{j=1}^{n} M_{g_i}^{j}$ = the total value of each column starting from column l in each row on the matrix

$\sum_{j=1}^{n} l_j$ = total value of l in each first column (lower)

$\sum_{j=1}^{n} m_j$ = total value of m in each first column (*medium*)

$\sum_{j=1}^{n} u_j$ = total value of u in each first column (*upper*)

Step 5. Specifies the priority vector value (V).

If the result obtained on each fuzzy matrix $M_2 \geq M_1 (M_2 = (l_2, m_2, u_2)$ and $M_1 = (l_1, m_1, u_1))$ then the vector value is indicated in the equation (4)

$$V(M_2 \geq M_1) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & others \end{cases} \quad (4)$$

Step 6. Determining the value of the fuzzification ordinate (d')

If the result of the fuzzy value is greater than $k, M_i (i = 1,2, \dots, k)$ then the vector value can be defined on the equation (5)

$$\begin{gathered} V(M \geq M_1, M_2, \dots, M_k) \\ = V(M \geq M_1), V(M \geq M_2), V(M \geq M_k) \\ = \min V(M \geq M_i) \end{gathered} \quad (5)$$

Step 7. Normalization of weight values of fuzzy vectors (W)

$$W' = (d'(K_1), d'(K_2), \dots, d'(K_n))^T \quad (6)$$

Where A_i $(i = 1,2, \dots, n)$ is n decision elemen $(d'(K_i))$.

Step 8. Specifies the weight vector of each criterion that presents the weights of each alternative.

$$s_{ij} = \frac{a_{ij} - a_j^{Min}}{a_j^{Max} - a_j^{Min}} \quad (7)$$

with,

$a_j^{Max} = max(a_{1j}, a_{2j}, \dots., a_{mj})$

$a_j^{Min} = min(a_{1j}, a_{2j}, \dots., a_{mj})$

i = 1,2, …, m

j = 1,2, …, n

After that, the normalization of the weight vector of the criterion is carried out which represents the weight of each alternative by the sum of the total value of the weight equal to one, which is expressed by the equation (8)

$$w_i = \frac{(d'(A_n))}{\sum_{j=1}^{n} d'(A_n)} \quad (8)$$

Step 9. Determining the outcome of decisions through rankings.

Calculating the total score for later rankings with the equation:

$$S_j = \sum (s_{ij})(w_i) \quad (9)$$

Information:

S_j = total score

s_{ij}= weight of each criteria that presents the weight of each alternative

w_i = weight of each criteria.

RESULTS AND DISCUSSION

Data collection of comparative values in pairs between criteria that influence customers in choosing a bank to open a savings account using a research questionnaire. The respondents selected were students with an age range of 18-23 years as many as 30 people. Respondents filled in paired comparison values between the two criteria using numerical variables i.e. from the scale of importance from 1 to 9. The criteria compared are administrative costs, interest rates, facilities, services, and the number of branch offices. For example, calculations were carried out using the FUZZY AHP method on one respondent's data, namely student 1 with the following completion steps

- Structure a hierarchy of problems
  There are five criteria that will be used, namely administrative costs (K_1), interest rates (K_2), facilities (K_3), services (K_4), dan the number of branch offices (K_5), with five alternatives as follows BRI (A_1), Mandiri (A_2), BNI (A_3), BSI (A_4), dan BTN (A_5). The hierarchy of the problem is described as follows

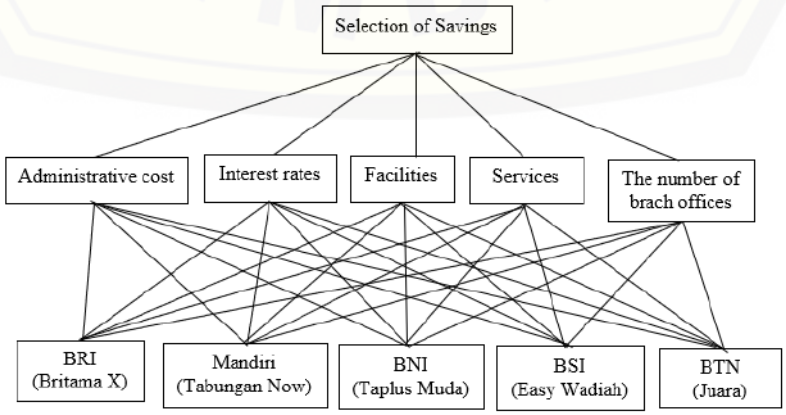

Figure 2. The hierarchical structure of the problem

- Change the weight of pairwise comparison assessments to TFN numbers
  The assessment weights of the respondents on the pairwise comparison matrix in Table 2 are converted into TFN numbers according to Table 1 presented in Table 3

Table 2. Pairwise comparison matrix

Criteria	K_1	K_2	K_3	K_4	K_5
K_1	1	7	-5	-5	7
K_2	-7	1	-7	-7	-7
K_3	5	7	1	7	7
K_4	5	7	-7	1	7
K_5	-7	7	-7	-7	1

Table 3. Paired comparison matrix that has been converted to the form TFN

Criteria	K_1			K_2			K_3			K_4			K_5		
	l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*U*	*l*	*m*	*u*
K_1	1	1	1	3	3,5	4	0,33	0,4	0,5	0,33	0,4	0,5	3	3,5	4
K_2	0,25	0,29	0,33	1	1	1	0,25	0,29	0,33	0,25	0,29	0,33	0,25	0,29	0,33
K_3	2	2,5	3	3	3,5	4	1	1	1	3	3,5	4	3	3,5	4
K_4	2	2,5	3	3	3,5	4	0,25	0,29	0,33	1	1	1	3	3,5	4
K_5	0,25	0,29	0,33	3	3,5	4	0,25	0,29	0,33	0,25	0,29	0,33	1	1	1

- Calculating the value of fuzzy synthesis (S_i)
  The calculation of the values of fuzzy synthesis begins by summing each of the values *l, m, u* in each column in Table 3. Furthermore, the value of fuzzy synthesis (S_i) is calculated using Equation (1). The calculation results are as follows

Table 4. Fuzzy synthesis value (S_i)

	l	*m*	*u*
K_1	0,16	0,21	0,28
K_2	0,04	0,05	0,07
K_3	9,25	0,34	0,44
K_4	0,20	0,26	0,35
K_5	0,10	0,13	0,17

- Determine priority vector value(V)
  The priority vector value (V) of each criterion is determined using the obtained fuzzy synthesis value and then calculated using Equation (4)

Table 5. Priority vector value (V)

	K_1	K_2	K_3	K_4	K_5
K_1	1	1	0,16	0,62	1
K_2	0	1	0	0	0

	K_1	K_2	K_3	K_4	K_5
K_3	1	1	1	1	1
K_4	1	1	0,53	1	1
K_5	0,04	1	0	0	1

- Determining defuzzification ordinate value (d')
  The minimum value of the priority vector (V) is used to determine the defuzzified ordinate value according to Equation (5). The result of the calculation of the defuzzified ordinate value is as follows:

  $d'(K_1) = \min(1; 1; 0{,}16; 0{,}62; 0) = 0{,}16$

  $d'(K_2) = \min(0; 1; 0; 0; 0) = 0$

  $d'(K_3) = \min(1; 1; 1; 1; 1) = 1$

  $d'(K_4) = \min(1; 1; 0{,}53; 1; 1) = 0{,}53$

  $d'(K_5) = \min(0{,}04; 1; 0; 0; 1) = 0$

- Normalization of fuzzy vector weights (W)
  Normalization of the weight value of the fuzzy vector (W) from the result of the calculation of the defuzzified ordinate value (d') using Equation (6), the result of which calculation is as follows:

$$W = \frac{(0{,}16;\ 0;\ 1;\ 0{,}53;\ 0)^T}{1{,}69} = (0{,}09; 0; 0{,}59; 0{,}31; 0)^T$$

- Defines the weight vector of the criteria that presents the alternative weight
  The calculation of the weight vector of each criterion presenting the weights of each alternative using a subjective approach using Equation (7) yields the values presented in Table 6

Table 6. Criteria weight vectors that present alternative weights

	K_1	K_2	K_3	K_4	K_5
A_1	0	1	1	0,62	1
A_2	0,3	1	0	0,92	0,38
A_3	0,2	1	0	0	0,19
A_4	1	0	1	0,46	0,19
A_5	0,7	1	1	1	0

The value of the alternative weight vector that has been obtained is then normalized using Equation (8), so that the results presented in Table 7 are obtained

Table 7. Normalization of the weight vector of the criterion presenting alternative weights

	K_1	K_2	K_3	K_4	K_5
A_1	0	0,25	0,33	0,21	0,57
A_2	0,14	0,25	0	0,31	0,21

	K_1	K_2	K_3	K_4	K_5
A_3	0,1	0,25	0	0	0,11
A_4	0,45	0	0,33	0,15	0,11
A_5	0,32	0,25	0,33	0,33	0

- Determining the results of decisions through rankings
  The last step is to calculate the final score using Equation (9) by multiplying the result of normalizing the value of an alternative weight vector by the weight of the fuzzy vector (*W*). The calculation results are as follows

$$S_{A_1} = (0 \times 0{,}09) + (0{,}25 \times 0) + (0{,}33 \times 0{,}59) + (0{,}21 \times 0{,}31) + (0{,}57 \times 0) = 0{,}259$$

$$S_{A_2} = (0{,}14 \times 0{,}09) + (0{,}25 \times 0) + (0 \times 0{,}59) + (0{,}31 \times 0{,}31) + (0{,}21 \times 0) = 0{,}109$$

$$S_{A_3} = (0{,}1 \times 0{,}09) + (0{,}25 \times 0) + (0 \times 0{,}59) + (0 \times 0{,}31) + (0{,}21 \times 0) = 0{,}009$$

$$S_{A_4} = (0{,}45 \times 0{,}09) + (0 \times 0) + (0{,}33 \times 0{,}59) + (0{,}15 \times 0{,}31) + (0{,}11 \times 0) = 0{,}282$$

$$S_{A_5} = (0{,}32 \times 0{,}09) + (0{,}25 \times 0) + (0{,}33 \times 0{,}59) + (0{,}33 \times 0{,}31) + (0 \times 0) = 0{,}326$$

The final score results along with the alternative bank rankings are presented in Table 8

Table 8. Final score and alternative ranking results for student 1

Variable	Bank Savings	Score	Ranking
A_5	BTN (Juara)	0,326	1
A_4	BSI (Easy Wadiah)	0,282	2
A_1	BRI (BritAmaX)	0,259	3
A_2	Mandiri (Tabungan Now)	0,109	4
A_3	BNI (Taplus Muda)	0,009	5

To calculate all the results of respondents, a matlab program is used which aims to simplify calculations and speed up time if you have more data on respondents of prospective customers. Program display as follows

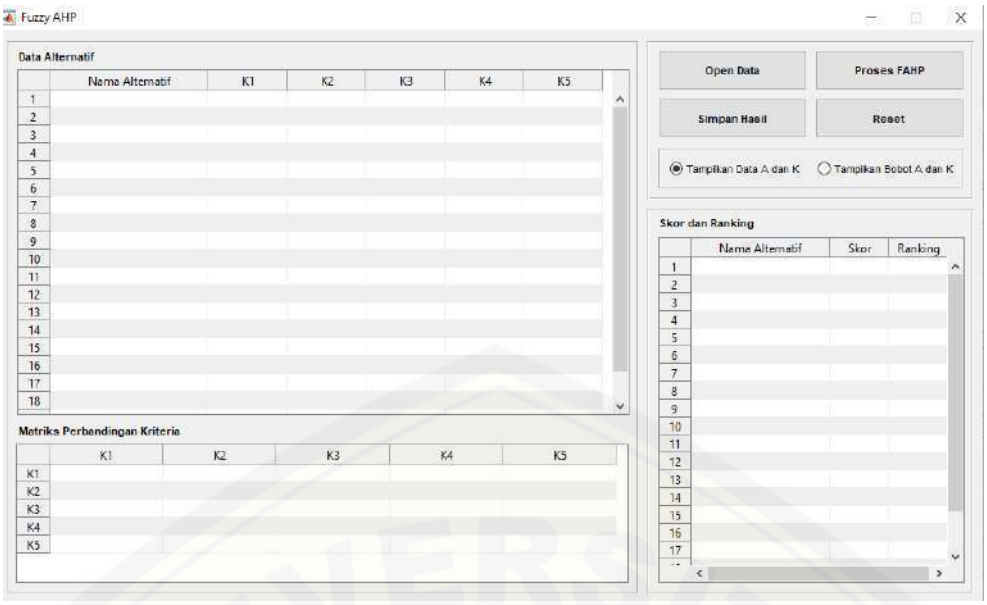

Figure 3. Program on MATLAB

The final score results and alternative rankings of all respondents (30 students) processed using the MATLAB program are presented in the following table

Table 9. Final score results and alternate rankings

Student	BRI BritamaX		Mandiri Tabungan Now		BNI Taplus Muda		BSI Easy Wadiah		BTN Juara	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
1	0,262	3	0,109	4	0,008	5	0,288	2	0,332	1
2	0,189	3	0,186	4	0,022	5	0,273	5	0,329	1
3	0,225	3	0,282	2	0,110	4	0,086	5	0,296	1
4	0,265	2	0,164	4	0	5	0,237	3	0,333	1
5	0,143	5	0,201	2	0,182	4	0,195	3	0,279	1
6	0,342	1	0,213	3	0,077	5	0,145	4	0,222	2
7	0,228	3	0,043	4	0,029	5	0,372	1	0,328	2
8	0,460	1	0,228	2	0,150	3	0,074	5	0,088	4
9	0,414	1	0,072	4	0,036	5	0,257	2	0,220	3
10	0,282	1	0,154	3	0,154	4	0,127	5	0,282	2
11	0,269	2	0,154	4	0	5	0,243	3	0,333	1
12	0,333	1	0	4	0	5	0,333	2	0,333	3
13	0,316	1	0,279	2	0,032	5	0,140	4	0,233	3
14	0,174	3	0,138	4	0,033	5	0,326	2	0,328	1
15	0	5	0,136	3	0,091	4	0,454	1	0,318	2
16	0,271	1	0,188	3	0,188	4	0,083	5	0,271	2
17	0,238	2	0,229	3	0	5	0,199	4	0,333	1
18	0,234	3	0,239	2	0	5	0,194	4	0,333	1
19	0,272	1	0,211	2	0,164	4	0,152	5	0,201	3
20	0,265	2	0,174	4	0,059	5	0,204	3	0,298	1
21	0,367	1	0,163	4	0,065	5	0,227	2	0,177	3
22	0,225	3	0,155	4	0,014	5	0,274	2	0,331	1
23	0,224	3	0,262	2	0	5	0,180	4	0,333	1
24	0,279	1	0,163	3	0,163	4	0,116	5	0,279	2
25	0,243	3	0,152	4	0,009	5	0,264	2	0,332	1
26	0,205	3	0,308	2	0	5	0,154	4	0,333	1
27	0,119	4	0,173	3	0,047	5	0,335	1	0,325	2

Student	BRI BritamaX		Mandiri Tabungan Now		BNI Taplus Muda		BSI Easy Wadiah		BTN Juara	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
28	0,205	3	0,307	2	0	5	0,154	4	0,333	1
29	0,214	3	0,296	2	0,049	5	0,124	4	0,317	1
30	0,086	4	0,208	3	0,053	5	0,328	1	0,324	2

Based on the results of the 30 students, then the weight vectors of each criterion and the final score of each alternative are added together and calculated on average, so that the results of the rankings are obtained in general as in Table 10 and the average results of weight vectors are generally presented in Table 11

Table 10. The results of the ranking in general

Variable	Bank Savings	Average Score	Ranking
A_5	BTN (Juara)	0,285	1
A_1	BRI (BritAma X)	0,245	2
A_4	BSI (Easy Wadiah)	0,218	3
A_2	Mandiri (Tabungan Now)	0,186	4
A_3	BNI (Taplus Muda)	0,058	5

Table 11. Average vector weighting criteria

K_1	K_2	K_3	K_4	K_5
0,153	0,145	0,254	0,369	0,079

The calculations carried out on 30 students obtained alternative savings from state-owned banks which are most often recommended when viewed from the average final score is the BTN Juara (A_5) savings with an average final score of 0.285. Meanwhile, the criteria that have the most important priority in choosing bank savings when viewed from the average weight vector (Table 11) are service criteria (K_4). The value for the service criteria (K_4) on the average weight vector of 30 students is 0.369. Judging from the final score that has been averaged in Table 10, the most recommended savings for students is the BTN Juara, where BTN has the highest or best service value among other state-owned banks.

CONCLUSIONS

The alternative that ranks first is the BTN Juara with an average final score of 0.285. Meanwhile, BNI Taplus Muda is an alternative that has the lowest average final score in the selection of savings with a value of 0.058. BTN Juara are most recommended for students in choosing savings according to the assessment of the 5 criteria as follows administrative costs, interest rates, facilities, services, and the number of branch offices of the bank.

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PENENTUAN LOKASI ATM BANK SYARIAH INDONESIA MENGGUNAKAN METODE *FUZZY C MEANS* DI KABUPATEN JEMBER

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ABSTRACT

Bank Syariah Indonesia is one of the banks resulting from the merger of three Islamic banks so that a strategy is needed by Islamic banks to attract customers' interest by providing easy transactions for customers, namely ATM's. location is something that needs to be considered, the accuracy of decisions in determining the location of ATM's that affect the number of customers. Aspects that affect the location of the ATM is the distance. One way to overcome this problem is to group the right area to determine the location of ATM's using the Fuzzy C Means (FCM) method. From the research that has been carried out the application of FCM based on the criteria for the location of the area, the number of residents, the number of Islamic religious schools, the population based on the level of welfare, and the center of the crowd with a grouping of 6 clusters. The exact location of BSI ATM's in Jember Regency is based on the number of clusters of the same criteria as the clusters based on the criteria used. Clustering validation uses the Silhoutte Index (SI) with a silhouette coefficient value of 0.62867.

Keywords : ATM, Fuzzy C Means, Silhoutte Index.

ABSTRAK

Bank Syariah Indonesia merupakan salah satu bank hasil merger dari tiga bank syariah sehingga perlunya strategi yang dilakukan oleh bank syariah untuk menarik minat nasabah dengan memberikan fasilitas kemudahan bertransaksi bagi nasabah yaitu ATM. Penentuan lokasi merupakan hal yang perlu diperhatikan, ketepatan keputusan dalam penentuan lokasi ATM mempengaruhi jumlah nasabah. Aspek yang mempengaruhi penentuan lokasi ATM adalah jarak. Salah satu cara mengatasi masalah tersebut dengan mengelompokkan wilayah yang tepat untuk penentuan lokasi ATM menggunakan metode *Fuzzy C Means* (FCM). Dari penelitian yang telah dilakukan penerapan metode FCM berdasarkan kriteria letak wilayah, jumlah penduduk, jumlah sekolah berbasis agama Islam, jumlah penduduk berdasarkan tigkat kesejahteraan, dan pusat keramaian dengan pengelompokan wilayah sebanyak 6 *cluster*. Lokasi yang tepat ATM BSI di Kabupaten Jember berdasarkan jumlah *cluster* kriteria yang sama dengan *cluster* acuan berdasarkan kriteria yang digunakan. Validasi *cluster*ing menggunakan *Silhoutte* Index (SI) dengan nilai koefisien silhouette yaitu 0,62867.

Kata Kunci : ATM, *Fuzzy C Means, Silhoutte Index*.

Kemajuan dunia perbankan dalam industri jasa keuangan memiliki peranan besar dalam menggerakkan ekonomi nasional. Bank merupakan badan usaha yang menghimpun dana

masyarakat dalam bentuk simpanan dan menyalurkan kembali kepada masyarakat dalam bentuk kredit atau lainnya dalam rangka meningkatkan pemerataan, pertumbuhan ekonomi, serta meningkatkan kesejahteraan taraf hidup masyarakat (Kasmir, 2014). Berdasarkan jenisnya bank ada dua yaitu bank konvensional dan bank syariah. Bank syariah adalah bank yang melaksanakan kegiatan usahanya berdasarkan prinsip syariah, yaitu peraturan yang digunakan berdasarkan hukum Islam antara bank dan pihak lain dalam penyimpan dana atau pembiayaan usaha atau kegiatan lainnya sesuai dengan nilai-nilai syariah (Ascarya, 2012). Salah satu bank syariah di Indoneia yaitu Bank Syariah Indonesia (BSI) yang merupakan bank hasil merger dari tiga bank syariah yaitu BNI Syariah, Mandiri Syariah dan BRI Syariah. Berbagai strategi yang dilakukan oleh bank syariah untuk menarik minat nasabah yaitu dengan menawarkan beragam produk syariah seperti tabungan haji, asuransi, investasi emas, dan lain sebagainya, memberikan nasabah kemudahan dalam bertransaksi di bank dan memberikan jaminan keamanan atas dana yang disimpan nasabah (Rianto, 2012). Bank Syariah Indonesia berusaha memberikan fasilitas kemudahan bertransaksi bagi nasabah yaitu ATM (Anjungan Tunai Mandiri). Pertimbangan BSI dalam penentuan lokasi ATM dengan memperkirakan lokasi-lokasi yang memungkinkan untuk dikunjungi banyak nasabah. Ketepatan keputusan dalam penentuan lokasi ATM mempengaruhi jumlah nasabah, yang pada akhirnya mempengaruhi pula besarnya keuntungan yang diperoleh oleh BSI.

Penelitian sebelumnya, Laelasari (2016) menggunakan *fuzzy c-means* dalam pengelompokan sapi potong sehingga dapat dihasilkan rekomendasi sapi potong berkualitas. Cristian (2019) menggunakan algoritma *fuzzy c-means* dalam penentuan lokasi gudang pendukung PT. XYZ dengan mengelompokkan 4 *cluster* yang optimum dengan jarak antara gerai dan gudang. Bagas (2021) menggunakan metode *clustering* dengan *fuzzy c-means* yang mampu menampilkan ruas jalan rawan kecelakaan sehingga lebih mudah dalam melakukan sosialisasi pencegahan daerah rawan kecelakaan. Berdasarkan latar belakang di atas, penulis tertarik mengaplikasikan metode *fuzzy c-means* pada permasalahan penentuan lokasi ATM BSI yang optimal di Kabupaten Jember. Oleh karena itu, penulis mengambil judul "Penentuan Lokasi ATM Bank Syariah Indonesia Menggunakan Metode *Fuzzy C Means* (Studi Kasus Enam Kecamatan di Kabupaten Jember)".

Tujuan penelitian ini untuk menentukan lokasi yang tepat untuk ATM BSI di Kabupaten Jember pada Kecamatan Sumbersari, Kecamatan Patrang, Kecamatan Arjasa, Kecamatan Pakusari, Kecamatan Sukorambi, dan Kecamatan Kaliwates berdasarkan analisis dari kriteria yang digunakan agar dapat memberi informasi kepada pihak BSI mengenai pengelompokan daerah yang tepat untuk penempatan lokasi ATM BSI di Kabupaten Jember dan mengurangi kegiatan transaksi di teller BSI serta memudahkan transaksi mandiri bagi nasabah karena ATM menyediakan layanan selama 24 jam.

Data yang digunakan dalam penelitian ini adalah data sukender yang diperoleh dari Badan Pusat Statistik (BPS) berupa data Jember dalam angka tahun 2021 dan Google Maps. Penelitian ini menggunakan beberapa definisi variabel dan pengukurannya yang digunakan pada Tabel 1.

Tabel 1. Definisi variabel dan pengukurannya

Variabel (i =1, 2, … , 40)	Definisi	Pengukuran
x_{i1}	*Longitude*	Koordinat
x_{i2}	*Latitude*	Koordinat
x_1	Jumlah penduduk usia 20-64 tahun	Jiwa
x_2	Jumlah sekolah berbasis agama Islam	Unit
x_3	Jumlah penduduk dengan tingkat kesejahteraan yang diukur berdasarkan pekerjaan PNS dan swasta	Jiwa
x_4	Jumlah pusat keramaian	Unit

a. Pengumpulan Data

Pengumpulan data dilakukan untuk mengumpulkan data dan informasi terkait yang dibutuhkan dalam proses pengolahan data. Tahap pengumpulan data dilakukan pada penelitian meliputi data sekunder yang yang diambil dari Badan Pusat Statistik (BPS) Kabupaten Jember berupa data Jember dalam Angka tahun 2021 dan *Google Maps*.

b. Pengolahan Data dengan *Fuzzy C Means*

Data mining merupakan proses menemukan pola dan pengetahuan dari sekumpulan data yang kemudian data tersebut diolah menggunakan algoritma (Jiawei, 2012). Data *clustering* merupakan salah satu metode data mining. *Clustering* adalah sebuah proses pengelompokan data dalam beberapa *cluster* sehingga data dalam *cluster* memiliki tingkat kemiripan yang maksimum dan data antar *cluster* memiliki kemiripan yang minimum (Prasetyo, 2014). Terdapat dua macam *clustering* yaitu *hard clustering* dan *fuzzy clustering*. *Fuzzy clustering* adalah dapat memberikan hasil pengelompokan bagi objek-objek yang tersebar tidak teratur, karena jika terdapat suatu data yang penyebarannya tidak teratur maka terdapat kemungkinan suatu titik data mempunyai karakteristik data dari *cluster* lain. Sehingga perlu adanya pembobotan kecenderungan titik data terhadap suatu *cluster*. Secara matematis, masalah fuzzy *cluster*ing telah dirumuskan oleh Bezdek pada tahun 1981 dalam bentuk optimasi kendala (Muzakir, 2014). Data yang diolah yaitu data letak wilayah yang diperoleh dari *longitude* dan *latitude* per kelurahan. Kemudian data diolah menjadi 6 *cluster* menggunakan metode *Fuzzy C Means*. *Fuzzy C Means* (FCM) merupakan salah satu algoritma *clustering* data. FCM diperkenalkan oleh Jim Bezdek pada tahun 1981. Metode ini termasuk suatu teknik pengklusteran data yang keberadaan tiap titik-titik data dalam *cluster* ditentukan oleh derajat keanggotaan. FCM menerapkan iterasi pada proses *clustering* data (Kusumadewi, 2010). Konsep dari *fuzzy c means*, pada proses pertama yaitu menentukan pusat *cluster* yang akan menandai lokasi rata-rata untuk tiap-tiap *cluster*. Kondisi tersebut, pusat *cluster* masih belum akurat. Setiap *cluster* memiliki derajat keanggotaan pada tiap-tiap titik data. Selanjutnya dengan memperbaiki pusat *cluster* dan derajat keanggotaan tiap-tiap titik data secara berulang, maka pusat *cluster* akan bergerak menuju lokasi yang tepat. Perulangan ini berdasarkan minimasi fungsi objektif yang menggambarkan jarak dari titik data yang diberikan ke pusat *cluster* yang terbobot oleh derajat keanggotaan titik data tersebut. *Output* dari FCM berupa deret pusat *cluster* dan beberapa derajat keanggotaan untuk setiap titik data (Ahmadi dkk, 2013).

Menurut Kusumadewi dan Purnomo (2004), algoritma *Fuzzy C-Means* (FCM) adalah sebagai berikut:

a. Memasukkan data yang akan di*cluster* dalam sebuah matriks X, berupa matriks berukuran $n \times m$.
   dengan
   n : jumlah data yang akan di*cluster*
   m : atribut setiap data.
   X_{ij} : data sampel ke-i $(i = 1,2,3, \dots, n)$, atribut ke-j $(j = 1,2,3, \dots, m)$
b. Menentukan jumlah *cluster* yang akan dibentuk (c), pangkat atau pembobot (w), maksimal iterasi (MaksIter), eror terkecil yang diharapkan (ε), fungsi objektif awal $(P_0 = 0)$, iterasi awal $(t = 1)$.
c. Membangkitkan setiap jumlah kolom (atribut):
   $$Q_j = \sum_{k=1}^{c} \mu_{ik} \quad (1)$$
   untuk $i = 1,2, \dots, n$; $k = 1,2, \dots, c$; dan $j = 1,2, .., m$ dengan
   Q_j : jumlah perkalian dari setiap kolom
   μ_{ik} : derajat keanggotaan dari X_i
   Dimana bentuk matriks partisi awal U sebagai berikut:
   $$U = \begin{bmatrix} \mu_{11}(x_1) & \mu_{12}(x_2) & \dots & \mu_{1c}(x_c) \\ \mu_{21}(x_1) & \mu_{22}(x_2) & \dots & \mu_{2c}(x_c) \\ \vdots & \vdots & \ddots & \vdots \\ \mu_{n1}(x_1) & \mu_{n2}(x_2) & \dots & \mu_{nc}(x_c) \end{bmatrix} \quad (2)$$
   Persamaan (2.4) menjelaskan matriks awal yang terbentuk dari setiap data akan di inputkan ke dalam perhitungan. Jumlah *cluster* yang akan dibentuk digambarkan oleh $\mu_{11}(\mu_1)$ sampai dengan $\mu_{1c}(x_c)$, sedangkan jumlah dari data yang akan di *cluster* digambarkan oleh $\mu_{11}(\mu_1)$ sampai dengan $\mu_{n1}(x_1)$. Dimana $0 < \mu_{ik} < 1$ dan jumlah setiap kolom pada matriks U harus sama dengan 1.
d. Menghitung pusat *cluster* V, untuk setiap *cluster*
   $$V_{kj} = \frac{\sum_{i=1}^{n} (\mu_{ik})^{w} * X_{ij}}{\sum_{i=1}^{n} (\mu_{ik})^{w}} \quad (3)$$
   untuk $k = 1,2, \dots, c$ dan $j = 1,2, \dots, m$ dengan
   V_{kj} : pusat *cluster*
   ${\mu_{ik}}^{w}$: matriks U dipangkatkan pembobot
   X_{ij} : sampel data ke-i pada variabel ke-j
   w : pangkat (pembobot)
e. Menghitung fungsi objektif pada iterasi ke-t, P_t:
   Fungsi objektif digunakan sebagai syarat perulangan agar mendapatkan pusat *cluster* yang tepat. Nilai iterasi awal $t = 1$
   $$P_t = \sum_{i=1}^{n} \sum_{k=1}^{c} \left(\left[\sum_{j=1}^{m} \left(X_{ij} - V_{kj} \right)^2 \right] (\mu_{ik})^{w} \right) \quad (4)$$
   dengan $i = 1,2, \dots, n$; $k = 1,2, \dots, c$; dan $j = 1,2, \dots, m$ dengan
   P_t : fungsi objektif
   X_{ij} : sampel data ke-i pada variabel ke-j
   V_{kj} : nilai pusat *cluster* ke-k pada variabel ke-j
   c : jumlah *cluster* yang berada di dalam X

n : jumlah data yang diproses

f. Menghitung perubahan matriks partisi pada setiap data pada setiap *cluster*

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]^{\frac{-1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]^{\frac{-1}{w-1}}} \quad (5)$$

untuk i=1,2,...,n dan $k = 1,2, \dots, c$ dengan

m : banyak variabel dengan ($j = 1,2,3, \dots, m$)

X_{ij} : sampel data ke-i pada variabel ke-j

V_{kj} : nilai pusat *cluster* ke-k pada variabel ke-j

g. Melakukan pengecekan kondisi berhenti

1) Jika ($|P_t - P_{t-1}| < \varepsilon$) atau ($t >$ MaksIter) maka berhenti;
2) Jika tidak $t = t + 1$, maka mengulangi langkah ke-4.

dengan

P_t : fungsi objektif

ε : eror terkecil yang diharapkan

t : iterasi awal

c. Validasi *Clustering*

Proses validasi *clustering* dengan menghitung validasi *Silhoutte Index* (SI). SI merupakan salah satu metode yang digunakan untuk memvalidasi *cluster* menggunakan nilai kohesi dan separasi. Terdapat dua komponen yaitu $a(i)$ dan $b(i)$. $a(i)$ adalah rata-rata jarak data ke-i terhadap semua data lainnya dalam satu *cluster*, sedangkan $b(i)$ adalah nilai minimum dari rata-rata jarak data ke-i terhadap semua data pada *cluster* lain (Aini, *et al*., 2014). Berikut persamaan dari $a(i)$.

$$a(i) = \frac{1}{|A|-1}\sum_{j \in A, j \neq i} d(i,j) \quad (6)$$

untuk $i = 1,2, \dots, j$ dengan

j : data lain dalam *cluster* A

$d(i,j)$: jarak data antara data i dan j

Berikut persamaan $b(i)$.

$$b(i) = min\ d(i,C) \quad (7)$$

dengan

$d(i,C)$: jarak rata-rata data i dengan data pada *cluster* lain C

Adapun persamaan *Silhoutte Index* (SI) berikut.

$$s(i) = \frac{b(i)-a(i)}{max(a(i),b(i))} \quad (8)$$

dengan

$a(i)$: rata-rata jarak data ke-i terhadap semua data lainnya dalam satu *cluster*

$b(i)$: nilai minimum dari rata-rata jarak data ke-i terhadap semua data pada *cluster* lain

$max(a,b)$: nilai maksimum dari nilai a dan b pada suatu data

Selanjutnya, menghitung nilai koefisien *silhouette* yang didefinisikan sebagai rata-rata $s(i)$ yaitu:

$$SC = \frac{1}{n}\sum_{i=1}^{n} s(i) \quad (9)$$

untuk $i = 1,2, \dots, n$ dengan

n : jumlah data

$s(i)$: nilai *silhouette index*

Hasil *clustering* terbaik jika koefisien *silhouette* bernilai maksimal yaitu dengan meminimalkan jarak daram kelompok serta memaksimalkan jarak antar kelompok. Interpretasi nilai koefisien *silhouette* ditunjukkan dalam Tabel 2 berikut.

Tabel 2. Interpretasi nilai *silhouette coefficient*

Silhouette Coefficient	**Interpretasi**
$\mathbf{0,7 < SC \leq 1}$	Struktur yang dihasilkan kuat
$\mathbf{0,5 < SC \leq 0,7}$	Struktur yang dihasilkan baik
$\mathbf{0,25 < SC \leq 0,5}$	Struktur yang dihasilkan lemah
$\mathbf{-1 \leq SC \leq 0,25}$	Tidak berstruktur

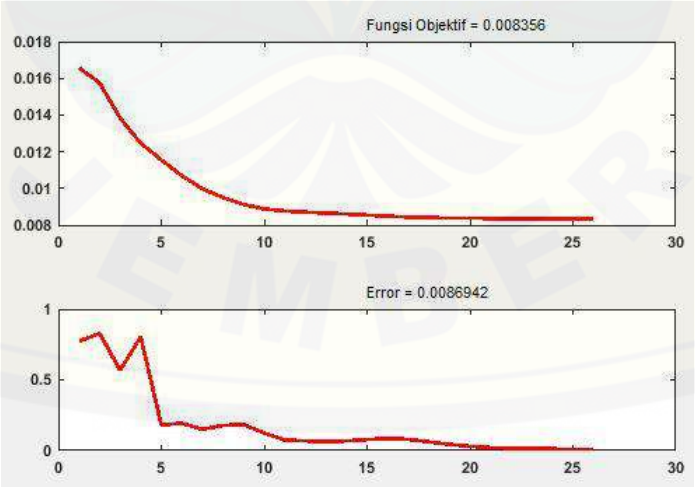
HASIL DAN PEMBAHASAN

Proses *clustering* dengan *fuzzy c means* dengan 6 *cluster* pada 40 data kelurahan di Kabupaten Jember pada Kecamatan Sumbersari, Kecamatan Patrang, Kecamatan Arjasa, Kecamatan Pakusari, Kecamatan Sukorambi, dan Kecamatan Kaliwates berdasarkan kriteria yang digunakan dengan pangkat pembobot (w) sebesar 3 dan maksimal iterasi (MaxIter) sebesar 500 dengan eror terkecil yang diharapkan (ε) sebesar 0,01. Perhitungan *fuzzy c means* dilakukan dengan memperbaiki matriks partisi pada setiap iterasi, hingga kondisi berhenti terpenuhi dan menghasilkan matriks partisi terakhir. Hasil perhitungan enam pusat *cluster* pada Tabel 3.

Tabel 3. Pusat *Cluster*

Pusat	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
Longitude	113,74127	113,76766	113,6664	113,6735	113,7143	113,7031
Latitude	-8,117691	-8,159427	-8,18429	-8,14914	-8,15351	-8,18313

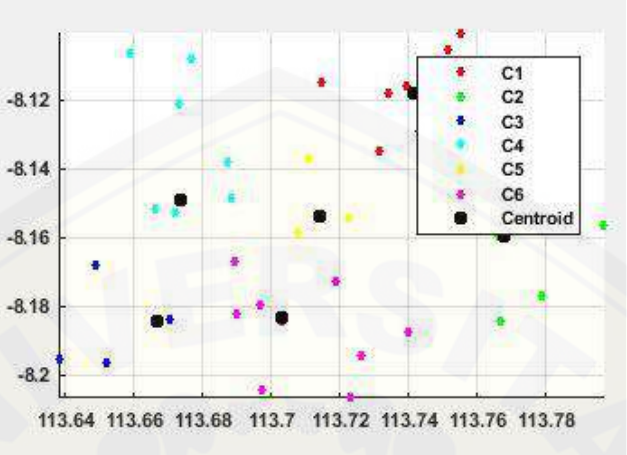
Setelah didapatkan pusat *cluster*, maka langkah selanjutnya yaitu menghitung fungsi objektif dan eror yang ditunjukkan pada Gambar 1 berikut.



Gambar 1. Grafik fungsi objektif dan eror

Gambar 1 menunjukkan grafik fungsi objektif dan eror, dimana iterasi keberapa perhitungan metode *fuzzy c means* konvergen. Berdasarkan pada grafik, fungsi objektif telah mendekati 0 pada iterasi ke

26 dengan nilai 0.008356 dan nilai eror yaitu 0.0086942. Derajat keanggotaan paling besar pada suatu data akan menentukan data tersebut masuk dalam *cluster*. Gambar 2 menampilkan visualisasi data hasil pengelompokan kelurahan menjadi 6 *cluster* berikut.



Gambar 2. Visualisasi data

Adapun hasil *cluster* acuan pada Tabel 4 berikut.

Tabel 4. Hasil *cluster* acuan

No	Nama Lokasi	*Longitude*	*Latitude*	*Cluster*
1	Krajingan, Sumbersari	113,723002	-8,20655700	6
2	Wirolegi, Sumbersari	113,739756	-8,18715500	6
3	Karangrejo, Sumbersari	113,726322	-8,19443868	6
4	Kebonsari, Sumbersari	113,703229	-8,18420407	6
5	Sumbersari, Sumbersari	113,718946	-8,17261866	6
6	Tegalgede, Sumbersari	113,722416	-8,15445429	5
7	Antirogo, Sumbersari	113,753719	-8,14652000	2
8	Gebang, Patrang	113,689206	-8,16702283	6
9	Jember Lor, Patrang	113,707853	-8,15849247	5
10	Patrang, Patrang	113,713655	-8,15371931	5
11	Baratan, Patrang	113,731438	-8,13450031	1
12	Bintoro, Patrang	113,710671	-8,13691400	5
13	Slawu, Patrang	113,688104	-8,14826116	4
14	Jumerto, Patrang	113,687026	-8,13795404	4
15	Banjarsengon, Patrang	113,673009	-8,12118096	4
16	Kemuning Lor, Arjasa	113,714585	-8,11482242	1
17	Darsono, Arjasa	113,733975	-8,11792400	1
18	Arjasa, Arjasa	113,739379	-8,11595100	1
19	Biting, Arjasa	113,762809	-8,11571900	1
20	Candijati, Arjasa	113,755055	-8,10030086	1
21	Kamal, Arjasa	113,751350	-8,10500100	1
22	Kertosari, Pakusari	113,766560	-8,1841300	2

No	Nama Lokasi	*Longitude*	*Latitude*	*Cluster*
23	Pakusari, Pakusari	113,778846	-8,1770170	2
24	Jatian, Pakusari	113,796976	-8,1564310	2
25	Subo, Pakusari	113,780661	-8,1423410	2
26	Sumberpinang, Pakusari	113,766159	-8,1596400	2
27	Bedadung, Pakusari	113,759462	-8,1320920	1
28	Patemon, Pakusari	113,742830	-8,1288480	1
29	Mangli, Kaliwates	113,652145	-8,1963382	3
30	Sempusari, Kaliwates	113,666110	-8,1848666	3
31	Kaliwates, Kaliwates	113,670338	-8,1837398	3
32	Tegal Besar, Kaliwates	113,697172	-8,2044423	6
33	Jember Kidul, Kaliwates	113,689731	-8,1819170	6
34	Kepatihan, Kaliwates	113,696814	-8,1797165	6
35	Kebon Agung, Kaliwates	113,672033	-8,1527940	4
36	Jubung, Sukorambi	113,638529	-8,1952930	3
37	Dukuh Mencek, Sukorambi	113,648859	-8,1680488	3
38	Sukorambi, Sukorambi	113,666310	-8,1514727	4
39	Karang Pring, Sukorambi	113,658865	-8,1060903	4
40	Klungkung, Sukorambi	113,676816	-8,1077320	4

Berdasarkan Tabel 4 hasil *clustering* wilayah per kelurahan yiatu:

a. *Cluster* pertama memuat sembilan kelurahan, yaitu Kelurahan Baratan, Kelurahan Kemuning Lor, Kelurahan Darsono, Kelurahan Arjasa, Kelurahan Biting, Kelurahan Candijati, Kelurahan Kamal, Kelurahan Bedadung dan Kelurahan Patemon.
b. *Cluster* kedua memuat enam kelurahan, yaitu Kelurahan Antirogo, Kelurahan Kertosari, Kelurahan Pakusari, Kelurahan Jatian, Kelurahan Subo, dan Kelurahan Sumberpinang.
c. *Cluster* ketiga memuat lima kelurahan, yaitu Kelurahan Mangli, Kelurahan Sempusari, Kelurahan Kaliwates, Kelurahan Jubung, Kelurahan Dukuh Mencek.
d. *Cluster* keempat memuat tujuh kelurahan, yaitu Kelurahan Slawu, Kelurahan Jumerto, Kelurahan Banjarsengon, Kelurahan Kebon Agung, Kelurahan Sukorambi, Kelurahan Karang Pring, dan Kelurahan Klungkung.
e. *Cluster* kelima memuat empat kelurahan, yaitu Kelurahan Tegalgede, Kelurahan Jember Lor, Kelurahan Patrang, dan Kelurahan Bintoro.
f. *Cluster* keenam memuat sembilan kelurahan, yaitu Kelurahan Krajingan, Kelurahan Wirolegi, Kelurahan Karangrejo, Kelurahan Kebonsari, Kelurahan Sumbersari, Kelurahan Gebang, Kelurahan Tegal Besar, Kelurahan Jember Kidul dan Kelurahan Kepatihan.

Selanjutnya dengan cara yang sama berlaku pada kriteria lain. Hasil *cluster* pada kriteria jumlah penduduk, jumlah sekolah berbasis agama Islam, jumlah penduduk berdasarkan kesejahteraan, dan jumlah pusat keramaian. Jika terdapat kelurahan yang memiliki jumlah *cluster* yang sama dengan *cluster* acuan lebih dari satu kelurahan maka dilakukan pembobotan berdasarkan tingkat kepentingan berdasarkan penilaian pihak bank dengan ketentuan berikut:

a. Jumlah pusat keramaian diberi bobot 4 dengan kategori sangat penting.
b. Jumlah penduduk diberi bobot 3 dengan kategori penting.

c. Jumlah penduduk dengan tingkat kesejahteraan diberi bobot 2 dengan kategori cukup penting.
d. Jumlah sekolah berbasis agama Islam diberi bobot 1 dengan kategori kurang penting.

Jika dalam pembobotan terdapat total bobot yang sama maka kelurahan yang dipilih berdasarkan kepentingan pihak bank. Adapun hasil *cluster* pada tiap kriteria pada Tabel 5.

Tabel 5. Hasil *cluster* pada tiap kriteria

No	Nama Lokasi	*Cluster*					Jumlah Kesamaan *Cluster*
		Acuan	x_1	x_2	x_3	x_4	
1	Baratan, Patrang	1	2	6	4	3	0
2	Kemuning Lor, Arjasa	1	5	4	5	1	1
3	Darsono, Arjasa	1	5	4	4	3	0
4	Arjasa, Arjasa	1	5	4	4	3	0
5	Biting, Arjasa	1	1	5	2	4	1
6	Candijati, Arjasa	1	1	5	6	4	1
7	Kamal, Arjasa	1	1	5	6	4	1
8	Bedadung, Pakusari	1	1	5	6	4	1
9	Patemon, Pakusari	1	1	5	2	1	2
10	Antirogo, Sumbersari	2	2	6	4	4	1
11	Kertosari, Pakusari	2	5	4	6	3	0
12	Pakusari, Pakusari	2	5	4	6	1	0
13	Jatian, Pakusari	2	1	5	4	4	0
14	Subo, Pakusari	2	1	5	6	4	0
15	Sumberpinang, Pakusari	2	5	4	6	4	0
16	Mangli, Kaliwates	3	3	1	3	2	2
17	Sempusari, Kaliwates	3	2	6	6	2	0
18	Kaliwates, Kaliwates	3	2	1	3	5	1
19	Jubung, Sukorambi	3	1	5	3	3	2
20	Dukuh Mencek, Sukorambi	3	5	4	5	4	2
21	Slawu, Patrang	4	5	4	3	1	1
22	Jumerto, Patrang	4	1	5	6	4	1
23	Banjarsengon, Patrang	4	1	5	6	4	1
24	Kebon Agung, Kaliwates	4	5	4	2	6	1
25	Sukorambi, Sukorambi	4	2	6	1	1	0
26	Karang Pring, Sukorambi	4	5	4	4	4	3
27	Klungkung, Sukorambi	4	1	5	3	4	1
28	Tegalgede, Sumbersari	5	5	4	2	3	5
29	Jember Lor, Patrang	5	3	1	3	5	1
30	Patrang, Patrang	5	3	1	3	2	0
31	Bintoro, Patrang	5	2	6	5	4	1

No	Nama Lokasi	*Cluster*					Jumlah Kesamaan *Cluster*
		Acuan	x_1	x_2	x_3	x_4	
32	Krajingan, Sumbersari	6	3	3	4	1	0
33	Wirolegi, Sumbersari	6	2	6	5	3	1
34	Karangrejo, Sumbersari	6	3	1	3	3	0
35	Kebonsari, Sumbersari	6	6	3	5	2	1
36	Sumbersari, Sumbersari	6	6	3	6	6	3
37	Gebang, Patrang	6	6	3	1	3	1
38	Tegal Besar, Kaliwates	6	4	3	1	2	0
39	Jember Kidul, Kaliwates	6	3	1	1	6	1
40	Kepatihan, Kaliwates	6	3	2	6	6	2

Selanjutnya berdasarkan Tabel 5 dengan cara yang sama berlaku pada kriteria lain. Hasil *cluster* pada kriteria jumlah penduduk, jumlah sekolah berbasis agama Islam, jumlah penduduk berdasarkan kesejahteraan, dan jumlah pusat keramaian terdapat pada Lampiran C. Jumlah tertinggi *cluster* yang sama dengan *cluster* acuan pada *cluster* pertama bernilai 2 yaitu Kelurahan Patemon. *Cluster* kedua bernilai 1 yaitu Kelurahan Antirogo. *Cluster* ketiga bernilai 2 yaitu Kelurahan Mangli dan Kelurahan Jubung. *Cluster* keempat bernilai 3 yaitu Kelurahan Karang Pring. *Cluster* kelima bernilai 1 yaitu Kelurahan Tegalgede, Kelurahan Jember Lor, dan Kelurahan Bintoro. *Cluster* keenam bernilai 3 yaitu Kelurahan Sumbersari. Pada *cluster* ketiga dan *cluster* kelima terdapat lebih dari satu kelurahan yang memiliki jumlah *cluster* yang sama dengan *cluster* acuan sehingga dilakukan pembobotan berdasarkan parameter kepentingan pada kriteria. Pada *cluster* ketiga Kelurahan Mangli memiliki total bobot yaitu 5 dan Kelurahan memiliki total bobot yaitu 6. Pada *cluster* kelima Kelurahan Tegalgede memiliki total bobot yaitu 3, Kelurahan Jember Lor memiliki total bobot yaitu 4, dan Kelurahan Bintoro memiliki total bobot yaitu 2. Sehingga bobot terbesar pada *cluster* ketiga yaitu Kelurahan Jubung dan pada *cluster* kelima yaitu Kelurahan Jember Lor. Oleh karena itu, penempatan lokasi ATM yang cocok yaitu Kelurahan Patemon, Kelurahan Antirogo, Kelurahan Jubung, Kelurahan Jember Lor dan Kelurahan Sumbersari.

Berdasarkan pengelompokan wilayah menggunakan *fuzzy c means*, nilai validasi *clustering* dengan *Silhoutte* Index (SI) setiap wilayah yang dapat dilihat pada Lampiran C. Apabila nilai silhouette mendekati 1, maka semakin baik *cluster* tersebut. Nilai koefisien *silhoutte* yang diperoleh yaitu 0,62867 menunjukkan bahwa struktur antara objek dan *cluster* yang terbentuk memperlihatkan hasil yang baik.

SIMPULAN

Berdasarkan penelitian yang dilakukan, dapat disimpulkan bahwa penentuan lokasi yang tepat untuk ATM BSI dapat menggunakan metode *fuzzy c means* dengan metode pengelompokan yang memiliki lebih dari satu kelompok. Hasil yang diperoleh menunjukkan bahwa pengelompokan kelurahan menjadi 6 *cluster* dengan kriteria letak wilayah sebagai *cluster* acuan, jumlah penduduk, jumlah sekolah berbasis agama Islam, jumlah penduduk berdasarkan pekerjaan dan jumlah pusat keramaian. *Cluster* pertama dan *cluster* keenam sebanyak 9 wilayah, *cluster* kedua sebanyak 6 wilayah, *cluster* ketiga sebanyak 5 wilayah, *cluster* keempat sebanyak 7 wilayah, *cluster* kelima

sebanyak 4 wilayah. Lokasi yang tepat ATM BSI di Kabupaten Jember yaitu Kelurahan Patemon, Kelurahan Antirogo, Kelurahan Jubung, Kelurahan Jember Lor dan Kelurahan Sumbersari. Nilai koefisien *silhoutte* yang diperoleh yaitu 0,62867 menunjukkan bahwa struktur antara objek dan *cluster* yang terbentuk memperlihatkan hasil yang baik.

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Application of Metaheuristic Algorithm for Solving Fully Fuzzy Linear Equations System

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Abstract. A linear equation is an equation in which each term contains a constant with a variable of degree one or single and can be described as a straight line in a Cartesian coordinate system. A Linear equations system is a collection of several linear equations. A system of linear equations whose coefficients and variables are fuzzy numbers is called a fully fuzzy linear equation system. This study aims to apply a metaheuristic algorithm to solve a system of fully fuzzy linear equations. The objective function used is the minimization objective function. At the same time, the metaheuristic algorithms used in this research are Particle Swarm Optimization (PSO), Firefly Algorithm (FA), and Cuckoo Search (CS). The input in this research is a fully fuzzy linear equation system matrix and parameters of the PSO, FA, and CS algorithms. The resulting output is the best objective function and the variable value of the fully fuzzy linear equations system. The work was compared for accuracy with the Gauss-Jordan elimination method from previous studies with the help of the Matlab programming language. The results obtained indicate that the Particle Swarm Optimization (PSO) algorithm is better at solving fully fuzzy linear equation systems than the Firefly Algorithm (FA) and Cuckoo Search (CS). This case can be seen from the value of the resulting objective function close to the value of the Gauss-Jordan elimination method.

INTRODUCTION

A linear equation is an equation in which each term contains a constant with a variable of degree one or single and can be described as a straight line in a Cartesian coordinate system. Linear equations system is one of the systems of equations in mathematics and is a collection of several linear equations. Two methods can solve a linear equations system: the analytical method and the numerical method. The solution of the linear equations system generally uses the analytical method. Still, if the case is a case that is difficult to solve using analytical methods, numerical methods are used to solve it [13].

Several numerical methods are often used to solve problems with systems of linear equations, namely the Half Interval Method, Linear Interpolation, Secant, Newton-Raphson, and others. However, there are weaknesses in these methods. This weakness has prompted new studies to solve linear equations systems, one of which is by using a metaheuristic algorithm. Metaheuristic algorithms can be defined as advanced heuristic-based algorithms to solve optimization problems efficiently. Some examples of metaheuristic algorithms include the Particle Swarm Optimization (PSO) algorithm, Firefly Algorithm (FA), Cuckoo Search (CS), etc.

Kusumadewi et al. [8] state that fuzzy logic is appropriate to map an input space into an output space. Lotfi A. Zadeh first introduced this concept in 1965. According to Zadeh [17], in fuzzy logic, the degree of membership is known, with a value range of 0 to 1. Based on this explanation, it can say that fuzzy membership lies in the interval [0,1]. There is a scientific development that combines equations systems with fuzzy numbers. A Linear equations system with constants in the form of fuzzy numbers is called a system of fuzzy linear equations. In addition to the fuzzy linear equation system, there is also a fully fuzzy linear equation system. The fully fuzzy linear equations system is a linear equations system in which the coefficients, variables, and constants are fuzzy numbers.

Based on the explanation, the authors are interested in solving the fully fuzzy linear equations system using a metaheuristic algorithm which will then test its accuracy by comparing it with the Gauss-Jordan elimination method. The metaheuristic algorithms in question are Particle Swarm Optimization (PSO), Firefly Algorithm (FA), and Cuckoo Search Algorithm (CS).

FUZZY LOGIC

Lotfi A. Zadeh first introduced fuzzy logic in 1965. According to Kusumadewi et al. [8], fuzzy logic is appropriate to map the input space into an output space. The workings of fuzzy logic consist of input, process, and output. Fuzzy logic has a concept that resembles the human way of thinking. Fuzzy logic can present human knowledge in a mathematical form that is more like human thinking. If, in strict logic, an element has two choices: a value of 1 or true and a value of 0 or false. Some basic definitions are reviewed [6, 7, 9, 10]

Definition 1
Set A is a fuzzy set *that* has a membership degree μ_A such that

$$\mu_A(x) = \begin{cases} 1, & if\ and\ only\ if\ x \in A \\ 0, & if\ and\ only\ if\ x \notin A \end{cases}$$

Definition 2
A fuzzy set A called convex if and only if for every $x_1, x_2 \in X$ and $\lambda \in [0,1]$ holds

$$\mu_A(\lambda x_1 + (1-\lambda)x_2) \geq min[\mu_A(x_1), \mu_A(x_2)]$$

Definition 3
A fuzzy set A called normal if and only if the degree of membership is not empty. In other words, we can find the point $x \in X$ with $\mu_A(x) = 1$.

Definition 4
If a fuzzy set is convex and normalized, and its membership function is defined in $\Re$ and is continuous, it is called a fuzzy number. So the fuzzy number in the fuzzy set is represented as an interval of real numbers with fuzzy boundaries.

Definition 5
A fuzzy number $\tilde{A} = (p, q, r)$ is called a triangular fuzzy number if it has a membership function structure such that $\tilde{A} \geq 0$ if and only if $p - q \geq 0$.

Definition 6
The triangular fuzzy number $\tilde{A} = (p, q, r)$ is said to be non-negative if $p \geq 0$.

Definition 7
Two fuzzy numbers $\tilde{A} = (p, q, r)$ and $\tilde{B} = (l, m, n)$ can be called equivalent if and only if $p = l, q = m$, and $r = n$.

Definition 8
A fuzzy number $\tilde{A} = (p, q, r)$ is called triangular fuzzy numbers if its membership function is of the following form:

$$\mu(x) = \begin{cases} 1 - \dfrac{a-x}{b}, & a - b \leq x \leq a, b > 0 \\ 1 - \dfrac{x-a}{c}, & a \leq x \leq a + c, c > 0 \\ 0, & others \end{cases}$$

Suppose $\tilde{A} = (p, q, r)$ and $\tilde{B} = (l, m, n)$ are two triangular fuzzy numbers; according to Dubois et al. [2], arithmetic operations on fuzzy numbers representing triangular curves are defined as follows:

- Addition: $\tilde{A} \oplus \tilde{B} = (p + l, q + m, r + n)$

- Subtraction: $\tilde{A} \ominus \tilde{B} = (p-l, p-m, r-n)$
- Multiplication: if $\tilde{A} \geq 0$ and $\tilde{B} \geq 0$ then $\tilde{A} \otimes \tilde{B} = (pl, pm+mq, pn+lr)$
- Scalar multiplication. Let λ be scalar then

$$\lambda \otimes \tilde{A} = \lambda \otimes (p,q,r) = \begin{cases} (\lambda p, \lambda q, \lambda r), & \lambda \geq 0 \\ (-\lambda p, -\lambda q, -\lambda r), & \lambda < 0 \end{cases}$$

FULLY FUZZY LINEAR EQUATIONS SYSTEM

The fully fuzzy linear equation system is a system of linear equations in which the coefficients, variables, and right-hand side constants are fuzzy numbers. According to Muruganandam et al. [10], the general form of a fully fuzzy linear equation system is as follows:

$$\begin{gathered} (\tilde{a}_{11} \otimes \tilde{x}_1) \oplus (\tilde{a}_{12} \otimes \tilde{x}_2) \oplus \ \ldots \ \oplus (\tilde{a}_{1n} \otimes \tilde{x}_n) = \tilde{b}_1 \\ (\tilde{a}_{21} \otimes \tilde{x}_1) \oplus (\tilde{a}_{22} \otimes \tilde{x}_2) \oplus \ \ldots \ \oplus (\tilde{a}_{2n} \otimes \tilde{x}_n) = \tilde{b}_2 \\ \vdots \\ (\tilde{a}_{n1} \otimes \tilde{x}_1) \oplus (\tilde{a}_{n2} \otimes \tilde{x}_2) \oplus \ \ldots \ \oplus (\tilde{a}_{nn} \otimes \tilde{x}_n) = \tilde{b}_n \end{gathered} \quad (1)$$

where
$\tilde{x}_i$ = Variable i-th
$\tilde{a}_{ij}$ = Coefficient of $\tilde{x}_i$
$\tilde{b}_i$ = right-hand side constants i-th
for $1 \leq i \leq n$ and $1 \leq j \leq n$

Based on Equation 1, the fully fuzzy linear equation system $\tilde{A} \otimes \tilde{x} = \tilde{b}$ can be written as follows:

$$(A, M, N) \otimes (x, y, z) = (b, h, g),$$

whereas by using arithmetic operations we get, $(Ax, Ay + Mx, Az + Nx) = (b, h, g)$,
so based on Definition 7, we get the form:

$$Ax = b;\ Ay + Mx = h;\ Az + Nx = g \quad (2)$$

PARTICLE SWARM OPTIMIZATION (PSO) ALGORITHM

Kennedy and Eberhart developed Particle Swarm Optimization (PSO) in 1995. Particle Swarm Optimization (PSO) is a swarm intelligence algorithm that simulates the social behavior of a group of birds. The PSO algorithm uses a population of a set of particles, where each particle represents a possible solution to an optimization problem. Each particle has a function value that is evaluated by the function to be optimized. The velocity (velocity) adapted from the search area to move and stored as the best position ever achieved. So that from the behavior of the bird collection, which is then used to solve optimization problems.

Each particle revolves around the multidimensional search space and adjusts its position based on the particle's experience and the neighboring particle's experience. Each particle has a position $z_i = [z_{i1}, z_{i2}, \ldots, z_{iN}]$ and a velocity $v_i = [v_{i1}, v_{i2}, \ldots, v_{iN}]$, where i represents the i-th particle and N represents the dimensions of the search space or the number of unknown variables. Initialization of the PSO algorithm begins by randomly assigning the initial position of the particle (solution) and then finding the optimal value. In each iteration, each particle updates its position following the two best values, namely the best solution that has been obtained by each particle (pbest) and the best solution in the population (gbest). After getting the best two values, the position and velocity of the particles are updated using the following equation [12]:

$$v_i^{t+1} = \theta v_i^t + c_1 r_1 (pbest_i^t - z_i^t) + c_2 r_2 (gbest_i^t - z_i^t) \quad (3)$$

$$z_i^{t+1} = z_i^t + v_i^{t+1} \quad (4)$$

where
θ = Weight coefficient of inertia
v_i^t = The velocity of the i-th particle in the t-th iteration
z_i^t = Solution (position) of the i-th particle in the t-th iteration
c_1, c_2 = Acceleration coefficient
r_1, r_2 = Random variable

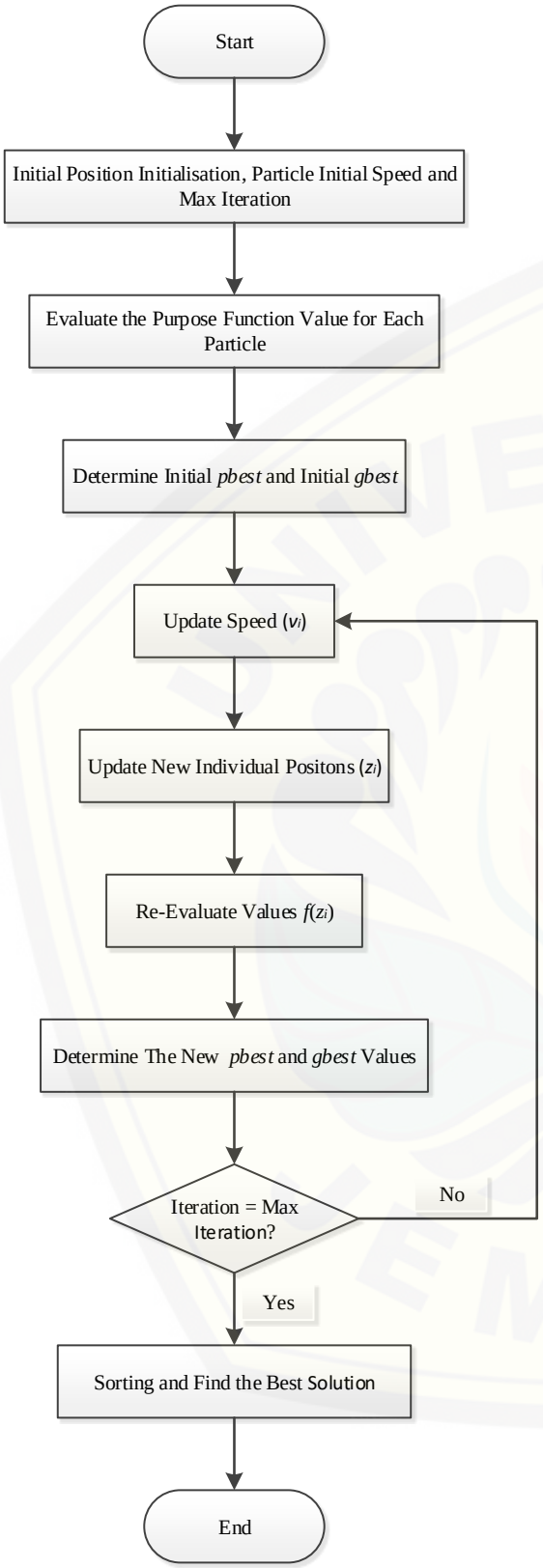

FIGURE 1. Particle Swarm Optimization algorithm

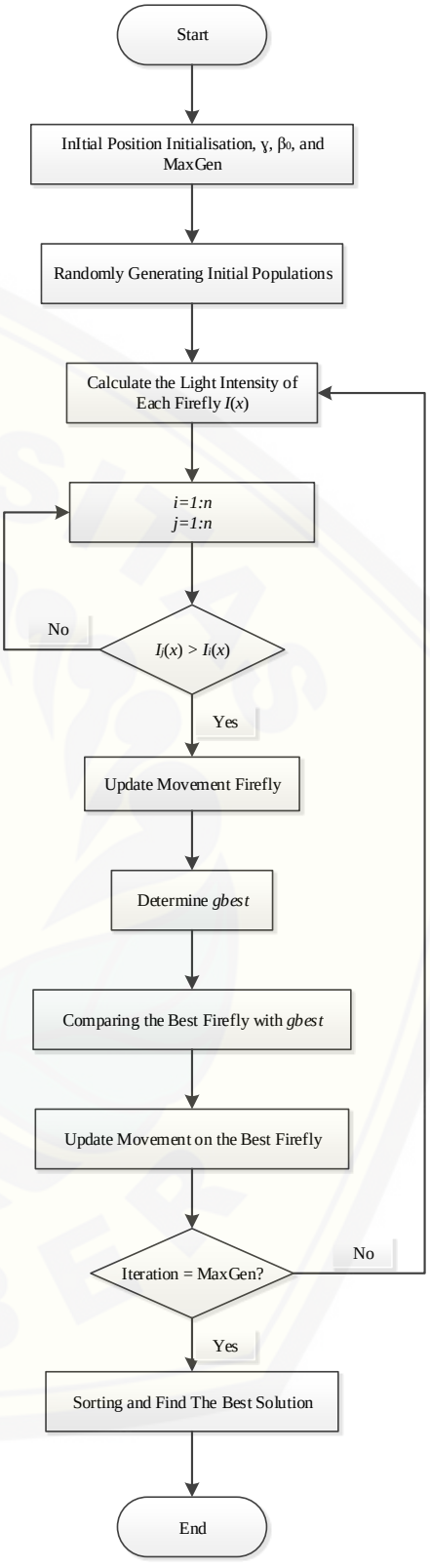

FIGURE 2. Firefly algorithm

The acceleration parameters c_1,c_2, r_1, and r_2, are random numbers with uniform distribution in the interval [0,1]. The parameters c_1 and c_2 are positive constants to control how far a particle will move in a single iteration. Low values allow the particle to travel far from the target area before pulling back, while high values result in a sudden movement towards the target area. Based on previous research, it has been shown that the acceleration coefficient must meet $c_1 + c_2 < 4(1 + \theta)$ and $c_1 = c_2$; assigning different values to c_1 and c_2 usually leads to an increase in work [3].

The weight coefficient of inertia (θ) serves to reduce the velocity of the particle. A high value of the weight coefficient of inertia causes an increase in the share of global exploration (global exploration), while a low value emphasizes local search. To not focus too much on one search and keep looking for a new search area in a specific dimension space, it is necessary to find a balanced value of the inertia weight coefficient (θ) to maintain global and local searches. The following formula can find the coefficient of inertia weight:

$$\theta = \theta_{max} - i\frac{\theta_{max} - \theta_{min}}{i_{max}} \tag{5}$$

where θ_{max} and θ_{min}n are the initial and final values of the coefficient of inertia weight, respectively, i_{max} is the maximum number of iterations used, and i is the iteration. Previous research shows that the weight coefficient of inertia must be in the range of 0 and 1 [4]. Particle Swarm Algorithm can be seen in the Figure 1.

FIREFLY ALGORITHM (FA)

The Firefly Algorithm (FA) was developed in late 2007 by Xin-She Yang at Cambridge University. This algorithm is based on the blinking pattern and behavior of fireflies. According to Yang [15], the FA uses three rules that are considered ideal, i.e.:

- Fireflies are *unisex*, so one firefly can be attracted to another firefly regardless of gender.
- The level of attraction of the firefly will be proportional to the level of brightness of the firefly. The farther the distance between the fireflies, the brightness level of the fireflies will decrease or disappear. So for every firefly that blinks, a less bright firefly (dimmer) will approach a brighter firefly. If neither of the two fireflies is brighter, then the fireflies will move randomly.
- The brightness level of fireflies will be determined by the objective function of the given problem.

There are two important problems in the FA algorithm: the variation of light intensity and the formulation of attractiveness. The objective function and attractiveness will determine the brightness of the firefly is proportional to the brightness. So for every two fireflies that blink, the firefly with the less bright light will move towards the firefly with the brighter light. The objective function influences the light intensity in fireflies. The level of light intensity for fireflies x is formulated as follows:

$$I(x) = \frac{1}{1 + f(x)} \tag{6}$$

where the value of $I(x)$ is the light intensity level on the fireflies x which is inversely proportional to the solution $f(x)$ or the objective function of the problem to be searched.

Attractiveness (β) is relative because the intensity of light depends on other fireflies. Therefore, the assessment results will differ depending on the distance between one firefly and another (r_{ij}). There are several cases where the light intensity will decrease from the source due to being absorbed by media such as air and others. So that attractiveness (β) can be determined with a distance (r) as follows:

$$\beta = \beta_0 e^{-\gamma r^2} \tag{7}$$

where β_0 is the attraction when there is no distance between the fireflies ($r = 0$) and $\gamma \in [0, \infty]$ is the light absorption coefficient [1].

The distance or the distance between the fireflies i and j at positions z_i and z_j is each a Cartesian distance which is formulated as follows:

$$r_{ij} = \| z_i - z_j \| = \sqrt{\sum_{t=1}^{n} \left(z_i^t - z_j^t\right)^2} \quad (8)$$

wherez_i^t is the t-th component of z_i on firefly i and $z_j^t$is the t-th component of z_j on firefly j.
The movement of firefly i due to attraction to other fireflies j, whose light intensity is brighter, is called movement. The movement causes the change in the position of the fireflies according to the following formula:

$$z_i^{t+1} = z_i^t + \beta\left(z_j^t - z_i^t\right) + \alpha\left(rand - \frac{1}{2}\right) \quad (9)$$

where the first term (z_i^t) is the old position of the firefly, the second term occurs because of interest; the third term is the random movement of the fireflies with being the coefficient of the random parameter, and rand is a random number in the interval $[0,1]$. The implementation of the FA algorithm usually uses $\beta_0 = 1, \alpha \in [0,1]$, and $\gamma \in [0,\infty]$ [1]. Firefly Algorithm can be seen in the Figure 2.

CUCKOO SEARCH ALGORITHM (CS)

Cuckoo Search (CS) is a metaheuristic algorithm developed by Xin-she Yang and Deb in 2009. This algorithm is inspired by the parasitic nature of several cuckoo species that lay eggs in the nests of other host birds (other species). Some host birds can come into direct conflict with annoying cuckoos. For example, if the host bird discovers that the egg in the nest is not its own, it will either discard the foreign egg or leave the nest and build the nest elsewhere. Some cuckoo species, such as the New World brood-parasite Tapera, have evolved to the point where the color and pattern of their eggs mimic those of the chosen host species [11]. Cuckoo Search Algorithm can be seen in the Figure 3.

Yang and Deb [14] used Lévy Flights, an extension of the random walk, to develop the Cuckoo Search (CS) algorithm. Lévy Flights is a random walk distributed by Lévy. Lévy Flights can map fruit flies in search of food. Fruit flies will focus on one point when looking for food; if fruit flies feel the food is running out, they will look elsewhere. This study also explained that Lévy Flights helped the CS algorithm in the search because the search steps were getting wider and wider. The CS algorithm uses Lévy Flights to get better accuracy than other optimization algorithms in determining the optimal point. Yang and Deb, in their research in 2009, stated that specific rules must be met in the use of this algorithm, i.e.:

- Each bird lays eggs at the same time and then throws the eggs in a randomly selected nest.
- Bird nests that are considered the best will be continued for the next generation.
- The number of bird nests in a colony is fixed.
- The probability of recognizing a cuckoo egg (P_a) placed in the host bird's nest is 0 and 1.

The last rule can be approximated with the parameter P_a to determine the worst solution of nests to be replaced with new nests at random. In the maximization problem, to simplify the application, a simple representation can be used: each egg in the nest represents a solution, and the eggs represent a new solution. The goal is to use a new solution that can replace the solution in the hive. Then the eggs in the nest will be selected and evolved by removing the eggs considered less good. In some cases, the original parent nest may have two eggs; in other words, a nest may contain more than one solution. However, to simplify the problem, a nest can only store one solution [15].
The step randomization process with Lévy Flights uses the following formula:

$$z_i^{(t+1)} = z_i^t + s \oplus Lévy\ (\alpha, \beta, \gamma, \delta) \quad (10)$$

where $z^{(t+1)}$ is the new solution, z_i^t is the old solution, , s is the step size associated with the level of the problem being worked on, and the sign $\oplus$ which means times or multiplies. Lévy Flights or what is called Lévy Stable Distribution in MATLAB, has several parameters, including [5]:

- Alpha (α) is the first form parameter with an interval of $0 < \alpha \leq 2$.
- Beta (β) is the second form parameter with an interval of $-1 \leq \beta \leq 1$.
- Gamma (γ) is a scale parameter that has an interval of $0 < \gamma < \infty$.
- Delta (δ) is a location parameter that has an interval of $-\infty < \delta < \infty$.

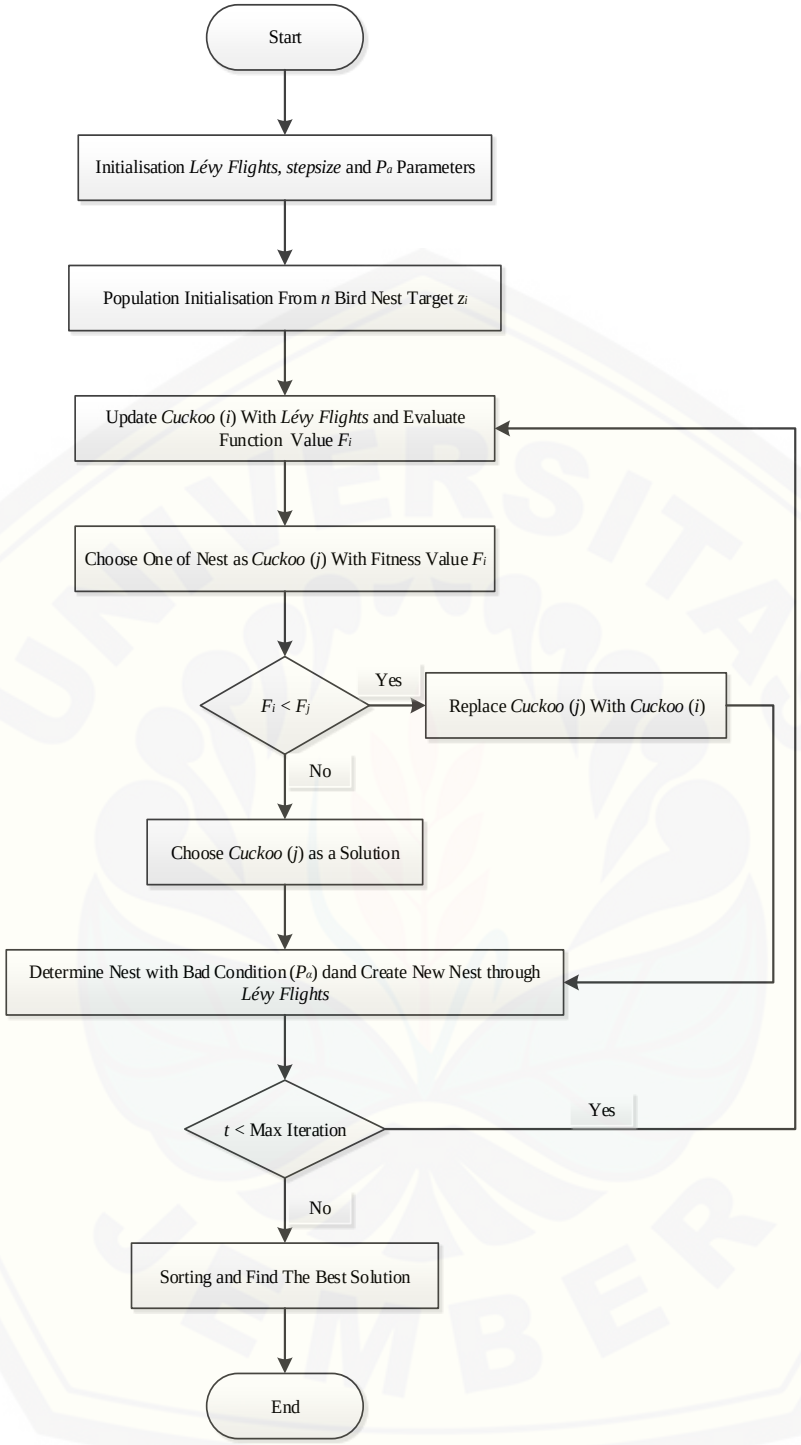

FIGURE 3. Cuckoo Search algorithm

RESULTS

In this study, the authors create a simulation program for the PSO, FA, and CS algorithms using MATLAB software in the form of a Graphical User Interface (GUI). The program is used to test the effect of the parameters of each algorithm. The results of comparing the PSO, FA and CS algorithms on the solution of a fully fuzzy linear equation system and the influence of these parameters can be seen in Figure 4.

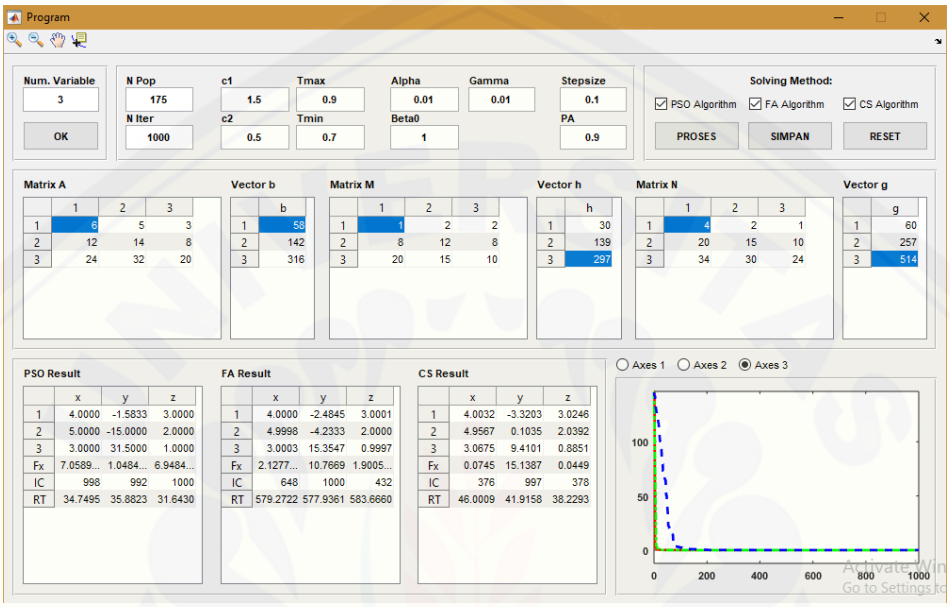

FIGURE 4. MATLAB program display

Numerical Results

The parameters tested: for PSO are $\theta_{max}, \theta_{min}, c_1,$ and c_2, for FA are α and γ, for CS are s and P_a. The program parameter test was carried out ten times. The best parameter values obtained are used for the final simulation of the PSO, FA, and CS algorithms. The reader can obtain the complete result of the parameter test through agustina.fmipa@unej.ac.id.

a. PSO Parameters

1. θ_{min} and θ_{max} Parameters Test
   The parameter values of tested are $0.1, 0.3, 0.5, 0.7$ and 0.9, with the supporting parameter values, namely, $N\ pop = 100, iteration = 1000, c_1 = 1$ and $c_2 = 1$. The best combination obtained is $\theta_{max} = 0.9$ and $\theta_{min} = 0.7$.
2. c_1 and c_2 Parameters Test
   The parameter values of tested are $0.5, 1, 1.5$ and 2, with the supporting parameter values, namely, $N\ pop = 100, iteration = 1000, \theta_{min} = 0.7$ and $\theta_{max} = 0.9$. The best combination obtained is $c_1 = 1.$ and $c_2 = 0.5$.

b. FA Parameters

1. α Parameter Test
   The parameter values of tested are $0.01, 0.05, 0.1, 0.3, 0.5, 0.7$ and 0.99, with the supporting parameter values, namely, $N\ pop = 100, iteration = 1000, \beta_0 = 1$ and $\gamma = 1$. The best value obtained is $\alpha = 0.01$. The results obtained from the test are shown in Figure 5, where the x axis represents the α and the y axis represents the total value of $f(x)$.

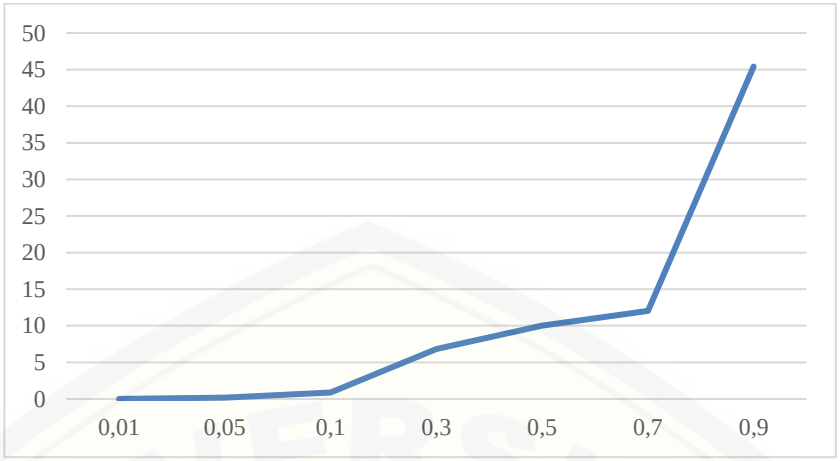

FIGURE 5. α parameter test results

2. γ Parameter Test

The parameter values of tested are $0.01, 0.05, 0.1, 0.2, 0.5, 1, 1.5, 2, 5$ and 10, with the supporting parameter values, namely, $N\,pop = 100, iteration = 1000, \alpha = 0.01$ and $\beta_0 = 1$. The best value obtained is $\gamma = 0.1$. The results obtained from the test are shown in Figure 6, where the x axis represents the γ and the y axis represents the total value of $f(x)$.

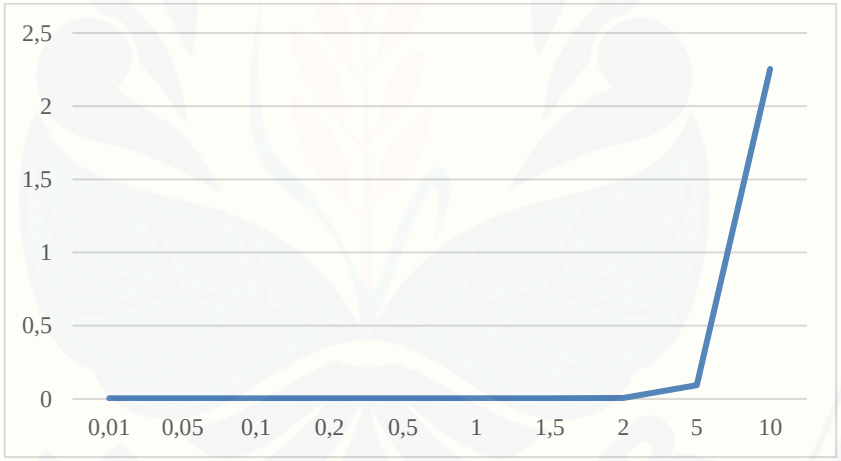

FIGURE 6. γ parameter test results

c. CS Parameters

1. s Parameter Test

The parameter values of tested are $0.01, 0.05, 0.1, 0.2, 0.5, 1, 1.5, 2, 5$ and 10, with the supporting parameter values, namely, $N\,pop = 100, iteration = 1000, P_a = 0.5$ and Lévy Flights parameter generated automatically in the MATLAB program. The best value obtained is s=0.1. The results obtained from the test are shown in Figure 7, where the x axis represents the s and the y axis represents the total value of $f(x)$.

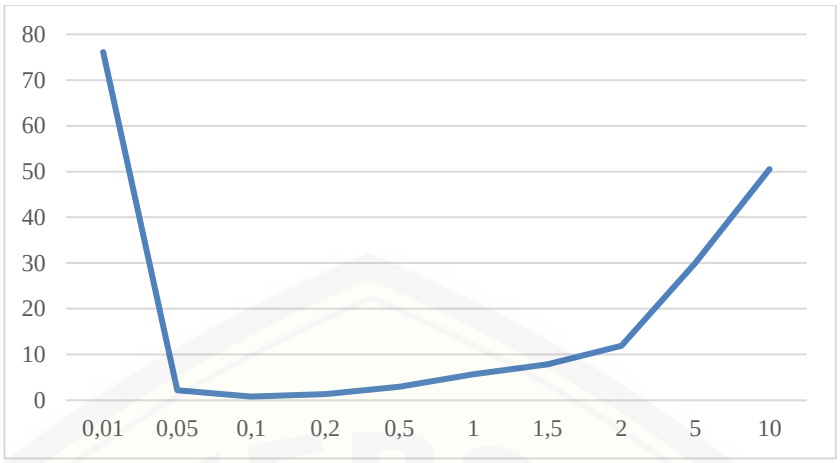

FIGURE 7. s parameter test results

2. P_a Parameter Test

The parameter values of tested are $0.1, 0.3, 0.5, 0.7$ and 0.9, , with the supporting parameter values, namely, $N\,pop = 100, iteration = 1000, s = 0.1$ and Lévy Flights parameters which are generated automatically in the MATLAB program. The best value obtained is $P_a = 0.9$. The results obtained from the test are shown in Figure 8, where the x axis represents the P_a and the y axis represents the total value of $f(x)$.

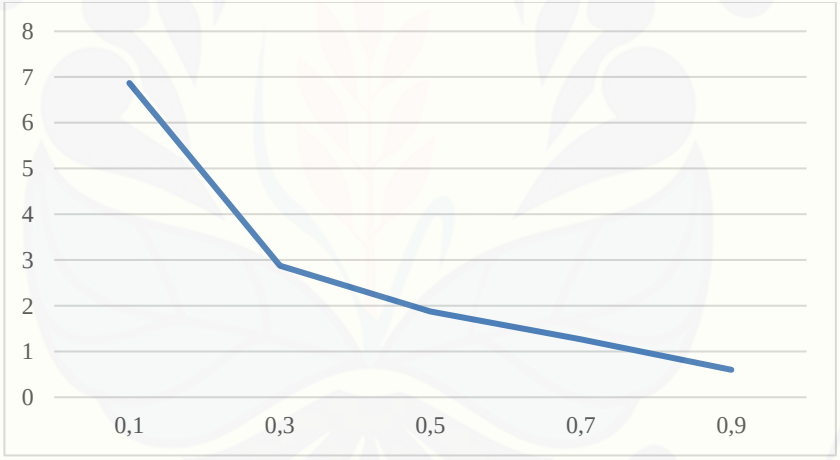

FIGURE 8. P_a parameter test results

d. $N\,pop$ Parameter Test

The parameter values of tested are $25, 50, 75, 100, 125, 150$ and 175, with iteration=1000. The parameter values of the PSO algorithm used are, $\theta_{max} = 0.9, \theta_{min} = 0.7, c_1 = 1.5$ and $c_2 = 0.5$. The parameter values of the FA algorithm used are $\alpha = 0.01, \beta_0 = 11$ and $\gamma = 0.1$. Meanwhile, the CS algorithm parameter values used are $s = 0.1, P_a = 0.9$ and the Lévy Flights parameter. The best value obtained is $N\,pop = 175$. The results obtained from the test are shown in Figure 9, where the x axis represents the $N\,pop$ and the y axis represents the total value of $f(x)$.

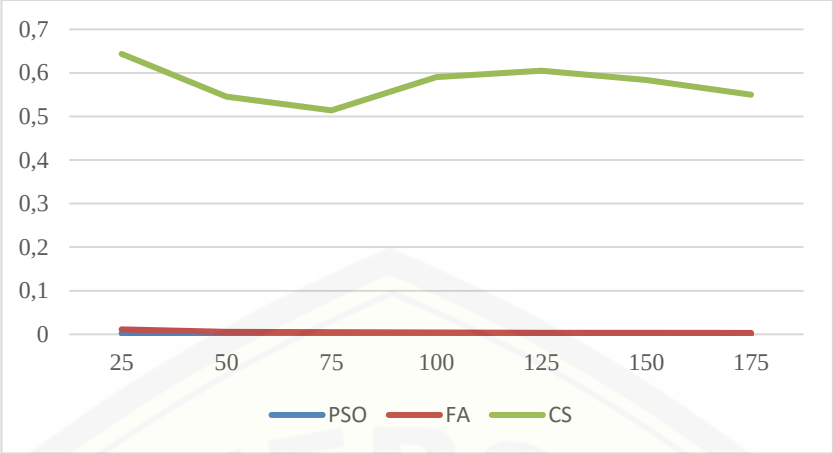

FIGURE 9. *N pop* parameter test results

Final Simulation

The results of the above calculations are used to solve the problem of a fully fuzzy linear equation system [10], which has been solved using Gauss Jordan elimination. The problem of the fully fuzzy linear equation system is

$$(6,1,4)\otimes\tilde{x}_1\oplus(5,2,2)\otimes\tilde{x}_2\oplus(3,2,1)\otimes\tilde{x}_3 = (58,30,60)$$

$$(12,8,20)\otimes\tilde{x}_1\oplus(14,12,15)\otimes\tilde{x}_2\oplus(8,8,10)\otimes\tilde{x}_3 = (142,139,257)$$

$$(24,10,34)\otimes\tilde{x}_1\oplus(32,30,30)\otimes\tilde{x}_2\oplus(20,19,24)\otimes\tilde{x}_3 = (216,297,514)$$

The solution of fully fuzzy linear equations using PSO, FA and CS algorithms and their comparison with Gauss-Jordan Elimination [10] can be seen in Table 1 with $\tilde{x}_1 = (x_1, y_1, z_1)$, $\tilde{x}_2 = (x_2, y_2, z_2)$, $\tilde{x}_3 = (x_3, y_3, z_3)$.

TABLE 1. Comparison results PSO, FA and CS algorithm with Gauss-Jordan elimination method

Variabel		PSO	FA	CS	Gauss-Jordan
$\tilde{x}_1$	x_1	4	4	4.001048	4
	y_1	−1.58488	−2.48789	−2.93751	1
	z_1	3	3	2.997779	3
$\tilde{x}_2$	x_2	5	4.999978	5.004566	5
	y_2	−14,9961	−4.1594	−0.06793	0.5
	z_2	2	2.000039	1.982704	2
$\tilde{x}_3$	x_3	3	3.000032	2.99109	3
	y_3	31.49563	15.24044	9.231667	0.5
	z_3	1	0.999918	1.032798	1

Based on Table 1, it is known that the calculation using the PSO algorithm is the result that is closest to the Gauss-Jordan elimination method, although there are still unequal values. Different values can be caused by using a small number of populations and iterations. However, this study shows that the PSO algorithm has better accuracy in solving a fully fuzzy linear equation system than the FA and CS algorithms.

CONCLUSION

Metaheuristic algorithms, especially Particle Swarm Optimization (PSO), Firefly Algorithm (FA), and Cuckoo Search (CS), can solve the fully fuzzy linear equation system. Based on the results obtained, the Particle Swarm Optimization (PSO) algorithm has the best accuracy results. It is close to the results of the Gauss-Jordan elimination method when compared to the Firefly Algorithm (FA) and Cuckoo Search (CS) algorithms.

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PENERAPAN *ANALYTICAL HIERARCHY PROCESS* DALAM PENENTUAN KE-LAYAKAN PRODUKSI
(Studi Kasus : Produksi Susu Argopuro Probolinggo)

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Abstract**:** *The feasibility of milk production can be seen from consumer satisfaction. Consumers are the key determining factor for the success or failure of a company in marketing its products. The quality standards of milk production by companies and consumers are different. The difference in arguments between companies and consumers is one of the factors for the feasibility of production. One of the industries that produce dairy cow's milk processing is KUD Argopuro which is developing in the Krucil area, Probolinggo Regency. Therefore, an effective method or method is needed for the advancement of the Argopuro KUD in determining the feasibility of milk production. The method applied here is the Analytical Hierarchy Process (AHP) method. The stages in the AHP method begin with identifying problems, making hierarchical structures, making pairwise comparison matrices, calculating eigenvector values, testing consistency using Consistency Index and calculating Consistency Ratio where if the Consistency Ratio value is 0.10 (10%) then the calculation results are declared consistent. Then, a sensitivity analysis was performed on changes in weights and rankings for each criterion. The results of the calculation show using the AHP method that milk production is suitable for consumption with the final value of Consistency Ratio 0.10 (10%). Sensitivity analysis on each criterion experienced a change in ranking when the weight value was lowered.*

Keywords*: Analytical Hierarchy Process*, sensitivity analysis, production feasibility, milk

***Abstrak*:** Kelayakan produksi susu dapat dilihat dari kepuasan konsumen. Konsumen menjadi faktor kunci penentu atas keberhasilan atau kegagalan suatu perusahaan di dalam memasarkan produknya Standar kualitas hasil produksi susu oleh perusahaan dengan konsumen berbeda. Perbedaan argumen antara perusahaan dan konsumen menjadi salah satu faktor kelayakan produksi. Salah satu industri yang memproduksi pengolahan susu sapi perah yaitu KUD Argopuro yang berkembang di daerah krucil Kabupaten Probolinggo. Oleh karena itu diperlukan metode atau cara efektif untuk kemajuan KUD Argopuro dalam menentukan kelayakan produksi susu. Metode yang diterapkan disini yaitu metode *Analytical Hierarchy Process* (AHP). Tahapan dalam metode AHP diawali proses mengidentifikasi masalah, pembuatan struktur hierarki, membuat matrik perbandingan berpasangan, menghitung nilai vektor eigen, menguji konsistensi menggunakan *Consistency Indeks* serta menghitung *Consistency Ratio* dimana jika nilai *Consistency Ratio* $\leq$ 0.10 (10%) maka hasil perhitungan dinyatakan konsisten. Kemudian, dilakukan analisis sensitivitas pada perubahan bobot serta rangking pada setiap kriteria. Hasil perhitungan menunjukkan dengan menggunakan metode AHP bahwa produksi susu layak dikonsumsi dengan nilai akhir *Consistency Ratio* $\leq$ 0.10 (10%). Analisis sensitivitas pada setiap kriteria mengalami perubahan rangking ketika nilai bobot diturunkan.
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***Kata Kunci**: Analytical Hierarchy Process, Analisis Sensitivitas, Kelayakan Produksi, Susu*

1. Pendahuluan

Saat ini perkembangan sektor industri semakin berkembang pesat. Sektor industri merupakan sektor yang memiliki peranan sangat penting dalam pembangunan ekonomi khususnya di negara seperti Indonesia. Kontribusi utama sektor industri terhadap pembangunan nasional diantaranya, pemenuhan kebutuhan bahan baku, terbukanya kesempatan kerja serta meningkatkan kesejahteraan masyarakat. Bahan baku merupakan salah satu faktor penting pada perusahaan dalam menunjang kelancaran dalam proses produksi. Menurut Sadono (2010) produksi merupakan suatu kegiatan berupa penciptaan nilai tambah dari input menjadi output secara efisien dan efektif, sehingga produk yang dihasilkan dapat dijual dengan harga yang kompetitif serta bermanfaat dalam memenuhi kebutuhan.

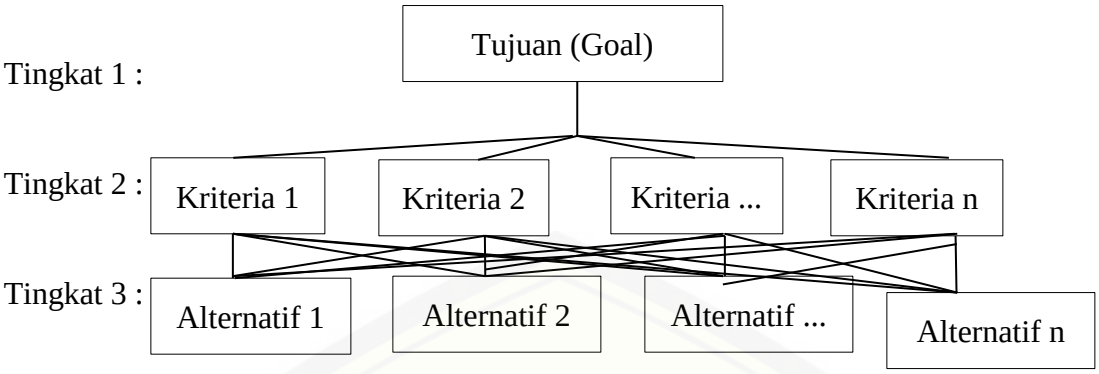
KUD Argopuro merupakah salah satu industri yang memproduksi pengolahan susu sapi perah yang berkembang di daerah krucil Kabupaten Probolinggo dan merupakan salah satu koperasi yang bekerja sama dengan peternak sapi di Jawa Timur. KUD Argopuro juga melakukan kegiatan pengolahan susu dan mendistribusikan produknya langsung ke konsumen melalui Rumah Susu KUD Argopuro Krucil. Susu yang telah diolah akan didistribusikan kepada konsumen. Konsumen menjadi faktor kunci penentu atas keberhasilan atau kegagalan suatu perusahaan di dalam memasarkan produknya. Kepuasan konsumen menjadi salah satu faktor bahwa susu layak dikonsumsi. Standar kualitas

hasil produksi susu oleh perusahaan dengan konsumen berbeda. Perbedaan argumen antara perusahaan dan konsumen menjadi salah satu faktor kelayakan produksi. Penelitian ini bertujuan untuk menerapkan metode *Analytical hierarchy proces* (AHP) dalam kelayakan produksi susu serta menganalisa sensitivitas pada perubahan bobot serta rangking pada setiap kriteria. Analisis sensivitas merupakan analisis yang dilakukan untuk mengetahui akibat dari perubahan parameter-parameter produksi terhadap perubahan kinerja sistem produksi dalam menghasilkan keuntungan (Winarti, 2016). Selain itu menururt Widaningsih (2017) analisis sensitivitas merupakan suatu pendekatan untuk menentukan nilai perubahan terkecil pada bobot kriteria. Bobot kriteria yang dimaksud berupa skor yang diberikan pada tiap kriteria.

2. Metode Penelitian

Metode yang diterapkan pada penelitian ini yaitu metode *Analytical hierarchy proces* (AHP). Pengambilan data primer diperoleh dari wawancara serta observasi secara langsung. Data yang diperoleh yaitu jumlah pakan sapi perah, jumlah air minum sapi perah, jumlah konsentrat, jumlah vitamin, luas kandang serta nama-nama peternak sapi perah. Pengolahan data dilakukan dengan menerapkan metode *Analytical hierarchy proces* (AHP), selanjutnya dilakukan analisis sensitivitas terhadap perubahan bobot dan ranking pada setiap kriteria. Langkah-langkah dalam menyelesaikan persoalan dengan metode AHP (Saaty, 1980) yaitu :

1. Mengidentifikasi masalah, mendefinisikan masalah yang akan diselesaikan secara jelas, detail dan mudah dipahami.
2. Penyusunan struktur hirarki permasalahan
   Membuat struktur hierarki yang diawali dengan tujuan utama. Setelah menyusun tujuan utama sebagai level teratas akan disusun level hirarki yang berada di bawahnya yaitu kriteria-kriteria yang cocok untuk mempertimbangkan atau menilai alternatif yang kita berikan dan menentukan alternatif tersebut. Hirarki dilanjutkan dengan subkriteria (jika mungkin diperlukan) seperti pada Gambar (2.2) berikut ini.



Gambar 2. 1 Struktur hierarki

3. Membuat matriks perbandingan berpasangan
   Matriks perbandingan berpasangan diisi menggunakan bilangan untuk merepresentasikan kepentingan relatif dari suatu elemen terhadap elemen yang lainnya. Perbandingan berpasangan tersebut diperoleh menggunakan skala penilaian perbandingan berpasangan.
4. Menghitung Vektor Eigen
   Perhitungan vektor eigen dilakukan pada matriks perbandingan berpasangan kriteria (tingkat kedua) dan alternatif (tingkat ketiga). Vektor eigen didapatkan dengan menjumlahkan nilai-nilai dari setiap baris serta membaginya dengan jumlah elemen untuk mendapatkan rata-rata.
5. Menghitung *Consistency Indeks*
   Pengukuran konsistensi dari suatu matriks perbandingan berpasangan didasarkan atas *eigen value* maksimum.
6. Menghitung *Consistency Ratio*
   Batas ketidakkonsistenan ditentukan dengan menggunakan *Consistency Ratio* (CR) yaitu perbandingan *Consistency Indeks* (CI) dengan nilai *Random Indeks* (RI). Jika *Consistency Ratio* (CR) $\leq$ 0.10 (10%) maka hasil perhitungan dinyatakan konsisten.

Selanjutnya dilakukan analisis sensitivitas pada perubahan bobot serta rangking pada setiap kriteria. Langkah-langkah yang akan dilakukan dalan analisis sensitivitas yaitu :

1. Setiap kriteria dihitung *Consistency Ratio* menggunakan metode AHP.
2. Perhitungan matriks faktor evaluasi total
   Matriks faktor evaluasi total diperoleh dari hasil seluruh evaluasi setiap kriteria dengan nilai masing-masing vektor eigen.
3. Perhitungan total ranking/prioritas global
   Total rangking/prioritas global diperoleh dengan mengalikan matriks faktor evaluasi total dengan matriks pembobotan hirarki yang diperoleh dari nilai vektor eigen kriteria yang dinormalisasi pada tahap metode AHP.

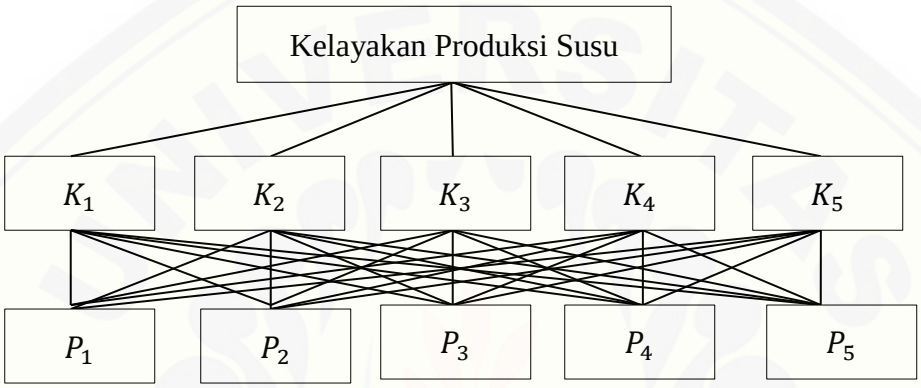
4. Analisis sensitivitas AHP pada bobot prioritas kriteria
   Perhitungan analisis sensitivitas pada perubahan bobot serta rangking terhadap setiap kriteria didapatkan dari tabel prioritas global.

3. Hasil dan Pembahasan

3.1 Pemodelan dan perhitungan menggunakan Metode AHP

a. Mengidentifikasi masalah
   Pada penelitian ini akan dilakukan identifikasi mengenai hal-hal yang mempengaruhi kelayakan produksi susu.

b. Penyusunan struktur hirarki



Gambar 4. 1 Struktur hirarki

c. Perhitungan Matriks Perbandingan Berpasangan Kriteria (tingkat dua)
   Tabel 4. 1 Matriks perbandingan berpasangan kriteria (tingkat dua)

	Pakan	Minum	Konsentrat	Vitamin	Luas Kandang
Pakan	1.000	2.000	3.000	4.000	5.000
Minum	0.500	1.000	3.000	4.000	6.000
Konsentrat	0.333	0.333	1.000	2.000	5.000
Vitamin	0.250	0.250	0.500	1.000	5.000
Luas Kandang	0.200	0.167	0.200	0.200	1.000
Jumlah	2.283	3.750	7.700	11.200	22.000

d. Perhitungan vektor eigen

Tabel 4. 2 Matriks perbandingan berpasangan kriteria dinormalisasi

	Pakan	Minum	Konsentrat	Vitamin	Luas Kandang	Vektor Eigen
Pakan	0.438	0.533	0.389	0.357	0.227	0.388
Minum	0.219	0.267	0.389	0.537	0.272	0.300
Konsentrat	0.145	0.088	0.129	0.178	0.227	0.153
Vitamin	0.109	0.067	0.064	0.089	0.227	0.111
Luas Kandang	0.087	0.044	0.044	0.017	0.045	0.043

$\lambda_{maksimum}$ = (2.283 x 0.388) + (3.750 x 0.300) + (7.700 x 0.153) + (11.200 x 0.111) + (22.000 x 0.043)

= 0.885 + 1.125 + 1.178 + 1.243 + 0.946

= 5.377 (4.1)

e. Perhitungan *consistency indeks*

Perhitungan consistency indeks merujuk pada persamaan (3.1). Matriks perbandingan berpasangan berordo 5 yaitu terdiri dari 5 kriteria, sehingga nilai consistency indeks yang diperoleh sebagai berikut.

$$CI = \frac{\lambda_{max}-n}{n-1} = \frac{5.377-5}{5-1} = \frac{0.377}{4} = 0.094 \quad (4.2)$$

f. Perhitungan *consistency rasio*

Perhitungan consistency rasio merujuk pada persamaan (3.2). Matriks perbandingan berpasangan berordo 5 maka nilai RI = 1.12 sehingga consistency rasio dapat dihitung seperti berikut.

$$CR = \frac{CI}{RI} = \frac{0.094}{1.12} = 0.084 \quad (4.3)$$

Karena $CR \leq 0.10$ maka hasil perhitungan dinyatakan konsisten.

Hasil akhir berupa *Consistency Ratio* yang ditunjukkan pada persamaan (4.3) yaitu 0.084. Angka tersebut berada dibawah angka *Consistency Ratio* sesuai dengan range menurut Saaty, jika *Consistency Ratio* bernilai ≤ 0.10 (10%) maka dapat dikatakan konsisten. Pada penelitian ini nilai *Consistency Ratio* ≤ 0.10 (10%) maka syarat konsistensi masih bisa diterima dan hasil perhitungan dinyatakan benar.

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3.2 Perhitungan Analisis Sensitivitas Pada Bobot Prioritas Kriteria Keputusan

1) Perhitungan Total Ranking/Prioritas Global

a. Faktor Evaluasi Total

Tabel 4. 3 Faktor evaluasi total

Faktor	Pakan Ternak (K_1)	Minum Ternak (K_2)	Konsentrat (K_3)	Vitamin (K_4)	Luas Kandang (K_5)
(P_1)	0.104	0.164	0.377	0.077	0.054
(P_2)	0.244	0.247	0.150	0.365	0.438
(P_3)	0.244	0.110	0.296	0.291	0.203
(P_4)	0.162	0.247	0.059	0.188	0.100
(P_5)	0.244	0.247	0.116	0.077	0.203

b. Total Ranking/Prioritas Global

Total rangking/prioritas global diperoleh dengan mengalikan matriks faktor evaluasi total dengan matriks pembobotan hirarki yang ditunjukkan pada persamaan 4.7 berikut.

$$\begin{bmatrix} 0.104 & 0.164 & 0.377 & 0.077 & 0.054 \\ 0.244 & 0.247 & 0.150 & 0.365 & 0.438 \\ 0.244 & 0.110 & 0.296 & 0.291 & 0.203 \\ 0.162 & 0.247 & 0.059 & 0.188 & 0.100 \\ 0.244 & 0.247 & 0.116 & 0.077 & 0.203 \end{bmatrix} \text{x} \begin{bmatrix} 0.388 \\ 0.300 \\ 0.153 \\ 0.111 \\ 0.043 \end{bmatrix} = \begin{bmatrix} 0.156 \\ 0.248 \\ 0.212 \\ 0.169 \\ 0.201 \end{bmatrix} \quad (4.7)$$

Matriks persamaan 4.7 diatas dapat juga disajikan seperti pada Tabel 4.8 berikut.

Tabel 4. 4 Prioritas global pemilihan peternak terbaik

Kriteria/Bobot	Pakan/ 0.388	Minum/ 0.300	Konsentrat/ 0.153	Vitamin /0.111	Luas Kandang /0.043	Prioritas Global
Alternatif						
P_1	0.104	0.164	0.377	0.077	0.054	0.156
P_2	0.244	0.247	0.150	0.365	0.438	0.248
P_3	0.244	0.110	0.296	0.291	0.203	0.212
P_4	0.162	0.247	0.059	0.188	0.100	0.169
P_5	0.244	0.247	0.116	0.077	0.203	0.201

Perubahan analisis sensitivitas tersebut dilakukan untuk memprediksi keadaan apabila terjadi perubahan musim sehingga mempengaruhi ketersediaan jumlah kriteria. Analisis sensitivitas pada setiap kriteria bobot prioritas terdiri dari pakan, minum, konsentrat, vitamin dan luas kandang dapat dilihat sebagai berikut.

a. Bobot Prioritas Pakan

Kriteria pakan memiliki bobot awal 0.388. Bobot prioritas pakan diturunkan menjadi 0.300 , 0.200 dan 0.160. Urutan prioritas berubah pada urutan keempat ketika bobot diturunkan menjadi 0.160. Sehingga bobot prioritas kriteria pakan sensitif ketika vektor eigen diubah dari 0.388 menjadi 0.160. Hal tersebut membuat ranking peternak mengalami perubahan urutan menjadi P_2, P_3 , P_5 , P_1 , P_4.

b. Bobot Prioritas Minum

Kriteria minum memiliki bobot awal 0.300. Bobot prioritas minum diturunkan menjadi 0.200 dan 0.100. Urutan prioritas berubah pada urutan keempat ketika bobot diturunkan menjadi 0.100. Sehingga bobot prioritas kriteria minum dikatakan sensitif ketika vektor eigen diubah dari 0.300 menjadi 0.100. Hal tersebut membuat ranking peternak mengalami perubahan urutan menjadi P_2, P_3 , P_5 , P_1 , P_4.

c. Bobot Prioritas Konsentrat

Kriteria konsentrat memiliki bobot awal 0,153. Bobot prioritas konsentrat diturunkan menjadi 0,100 dan 0,050. Urutan prioritas berubah pada urutan kedua ketika bobot diturunkan menjadi 0,050. Sehingga bobot prioritas kriteria konsentrat sensitif ketika vektor eigen diubah dari 0, 153 menjadi 0.050. Hal tersebut membuat ranking peternak mengalami perubahan urutan menjadi P_2, P_5 , P_3 , P_1 , P_4.

d. Bobot Prioritas Vitamin

Kriteria vitamin memiliki bobot awal 0.111. Bobot prioritas vitamin diturunkan menjadi 0.100 dan 0.050. Urutan prioritas berubah pada urutan keempat ketika bobot diturunkan menjadi 0.050. Sehingga bobot prioritas kriteria vitamin sensitif jika vektor eigen diubah dari 0.111 menjadi 0.050. Hal tersebut membuat ranking peternak mengalami perubahan urutan menjadi P_2, P_5 , P_3 , P_1 , P_4.

e. Bobot Luas Kandang

Kriteria vitamin memiliki bobot awal 0.043. Urutan prioritas tidak berubah ketika bobot diturunkan hingga 0.010. Hal tersebut membuat ranking peternak tidak mengalami perubahan.

4. Kesimpulan dan Saran

4.1 Kesimpulan

a. Metode *Analitycal Hierarchy Process* (AHP) dapat diterapkan pada permasalahan kelayakan produksi susu Argopuro Probolinggo. Nilai *consistency rasio* yang diperoleh yaitu 0.084, dimana nilai tersebut ≤ 0.10 (batas kekonsistenan). Nilai 0.084 menunjukkan bahwa produksi susu Argopuro Probolinggo layak dikonsumi
b. Perhitungan Analisis sensitivitas pada perubahan bobot serta rangking pada setiap

kriteria pakan, minum, konsentrat, vitamin dan luas kandang berturut-turut sebesar 0.388, 0.300, 0.153, 0.111 dan 0.043 (P_2, P_3, P_5, P_4, P_1). Kriteria pakan, minum, konsentrat dan vitamin mengalami perubahan rangking saat nilai bobot awal diturunkan sedangkan kriteria luas kandang tidak mengalami perubahan rangking dikarenakan luas kandang sapi perah memiliki ukuran yang sama. Perubahan ranking pada kriteria pakan terjadi ketika bobot diturunkan menjadi 0.160 (P_2, P_3 , P_5 , P_1 , P_4), kriteria minum diturunkan menjadi 0.100 (P_2, P_3 , P_5 , P_1 , P_4), kriteria konsentrat diturunkan menjadi 0.050 (P_2, P_5 , P_3 , P_1 , P_4) dan kriteria vitamin diturunkan menjadi 0.050 (P_2, P_5 , P_3 , P_1 , P_4).

4.2 Saran

Berdasarkan hasil penelitian diatas, penulis menyarankan pada penelitian yang sejenis dapat mengerjakan permasalahan kelayakan produksi dengan menggunakan metode *Multi Attribute Decision Making* (MADM) lainnya. Peneliti selanjutnya juga dapat mengembangkan analisis sensitivitas terhadap bobot prioritas alternatif keputusan serta kriteria yang mempengarui permasalahan tersebut.

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Application of Markov Chain in Predicting Sugar Production at Candi Baru Sugar Factory, Sidoarjo

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Abstract. Granulated sugar is a sugar commonly used daily to manufacture food and beverages. The demand for granulated sugar continues to increase, but the number of sugar factories and the area of sugar cane in Indonesia is decreasing. This causes a gap between the demand for sugar which continues to increase, and the production of granulated sugar continues to decline, resulting in Indonesia being the largest country importer of sugar. The imbalance between the demand and production of granulated sugar At Candi Baru Sugar Factory, Sidoarjo, East Java, resulted in not achieving the target to meet these needs. Therefore, predictions are made to get an overview of production planning to optimize granulated sugar production so that sugar needs can be met. The prediction method used at the Candi Baru sugar factory, Sidoarjo, East Java, for the 2022 milling period is the Markov Chain method with a four-state divisor, namely drastically down, down, up, and up drastically. The application of Markov Chains produces predictions for each state. It is predicted that the production of sugar with the highest percentage for May – December upstate.

Keywords: *Markov Chain, Prediction, Granulated Sugar Production*
2020 *Mathematical Subject Classification* : 90C40

INTRODUCTION

Sugar is a natural sweetener and a simple carbohydrate that is easily soluble in water and turned into energy for the body [14]. Granulated sugar is a type of sugar used daily in the manufacture of food or drinks and comes from sugar cane juice which is crystallized into sugar granules. Demand for granulated sugar continues to increase in Indonesia, caused of several things: the habit of consuming granulated sugar, population growth, community welfare, and the development of industries that use granulated sugar as raw material [8]. Indonesia has the potential as the largest sugar-producing country in the world. Still, in reality, the number of sugar factories is decreasing, and the sugar cane area is decreasing, so the State of Indonesia is currently the largest sugar importer. The gap between the demand for sugar continues to increase, and production continues to decline. Production planning is needed to optimize the production strategy so that sugar needs and requests are met. Production planning is an activity related to the process of converting raw materials into an item [20]. Production planning determine based on the results of forecasting or predictions. Markov Chain can use as a prediction method. Markov Chain studies the properties of a variable in the present and past to estimate variables in the future. The result of Markov Chain analysis is probabilistic information. This analysis uses to assist decision-making. PG Candi Baru Sidoarjo is one of the companies that produce granulated sugar, which is experiencing an imbalance between demand and realization of sugar. From the description above, researchers are interested in conducting research, namely applying the Markov Chain in predicting sugar production with the help of QM software for Windows.

METHODOLOGY

Data is a collection of facts that can be trusted to be accurate; the available data is often raw data that has not been compiled and has no information, so the data needs to be processed in such a way to get information. Statistics can be divided into two types: descriptive and inductive. An example of descriptive statistics is frequency distribution, where data are arranged according to size or category and presented in tables or graphs. The steps in forming the frequency distribution are as follows [22]:

a. Determine the number of classes
   The number of classes can be determined freely according to needs or using the Sturges formula below

$$K = 1 + 3.3 \log a \tag{1}$$

   with K is the number of classes, and a is the number of data.

b. Determine the length of the class interval
   In determining the class length, the data's distance or range must be known. The range is the distance between the largest data and the smallest data

$$R = largest\ data - smallest\ data$$

   The known range is divided by the number of classes (K), as follows [22]

$$I = \frac{R}{K} \tag{2}$$

   with I is class length, R is *the range, and* K *is* the number of classes.

Inductive statistics are statistics that assess characteristics, predict and draw general conclusions. The probability of an event is a measure of the likelihood of an event occurring in the future. Probability has a conditional event rule that the occurrence of one event is used as a condition for the occurrence of another event which is stated in the following Equation: [22]

$$P(A|B) = \frac{P(A \cap B)}{P(B)}; P(B) \neq 0 \tag{3}$$

with $P(A|B)$ is conditional probability of event A if event B is known, $P(A \cap B)$ is the probability that both A and B occur at the same time, and (B) is probability of event B.

A Markov Chain is a series of event processes in which the conditional probability of future events depends on the current events. The results of Markov Chain analysis are probabilistic information that can be used to assist decision-making [1]. Markov analysis is a special form of probabilistic model, which is more commonly called a stochastic process. A stochastic process is a set of random variables. All possible values that can occur in the random variable of the stochastic process are called state space, so the stochastic process is expressed in Equation. [17]

$$X = \{X(t), t \in T\} \tag{4}$$

with X is set of random variables, $X(t)$ is random variables, T is time index set, and t is time.

A stochastic process X_t is said to have Markov properties if for $t = 1,2,3$ ... it has a transition probability or a probability of moving state i at time t to state j at time $t + 1$, which is called P_{ij} [17].

The Markov Chain is represented in a transition probability matrix called a one-step transition probability matrix. P_{ij} is the probability is in the state i, then the process will transition to the state j, as in the matrix P below [17]. The relationship between states can represent in Figure 1.

$$P = \begin{bmatrix} P_{00} & P_{01} & \cdots & P_{0j} \\ P_{10} & P_{11} & \cdots & P_{1J} \\ \vdots & \vdots & \vdots & \vdots \\ p_{i0} & P_{ii} & \cdots & P_{ij} \end{bmatrix}$$

with $P_{ij} \geq 0;\ i,j \geq 0;\ \sum_{j=0}^{\infty} P_{ij} = 1;\ i = 0,1,\ldots,$ P is a one-step transition probability matrix, and P_{ij} is transition probability from *state* i to *state* j.

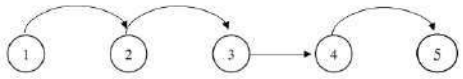


FIGURE 1. Relationship between states

The one-step transition probability matrix is the probability of the initial state of a system so that to find out the conditional probability that a system in the state i will be in a state j, an n-step transition probability $\left(P_{ij}^{n}\right)$ is performed. So to calculate the probability of an n-step transition, you can use the Chapman-Kolmogorov equation as follows [17]

$$P^n = P^{n-1}P \tag{5}$$

with P^n is probability of the n^{th} state transition, $n = 1, 2, ...$, P^{n-1} is a probability of state transition at n-1, and P is transition probability matrix P.

The state of the Markov Chain transition matrix for each state in each -step generally cannot be determined with certainty, so a probability for each state in the initial conditions is needed, called the initial state vector (v^0). The initial state vector indicates an equal chance of every state in a system starting a transition [11].

$$v^0 = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_k \end{bmatrix}$$

where v_1 is the probability at state 1, v_2 is the probability at state 2, and v_k is the probability at state k. If P^n is the transition matrix of the Markov Chain and v^0 is the initial state vector, then

$$v^n = v^0 P^n \tag{6}$$

with v^n is state vector, $n \geq 1$, v^0 is initial state vector, and P^n is transition probability matrix, $n \geq 1$

This iterative process is used to predict the probability of the future state of the transition process [10]. After performing the n-step transition process, the system reaches a steady state where the transition probability has reached a fixed condition so that the transition probability value does not change again after makin n-step transitions. Repeated probability calculations will take time, so the calculation process is not efficient. In an ergodic (recurrent and aperiodic) Markov Chain, the steady-state probability can be solved using the following Equation [17]

$$\pi = P\pi \tag{7}$$

RESULTS AND DISCUSSION

The data was used during the sugarcane milling period from 2010 – 2021. According to the data obtained, the Candi Baru sugarcane milling period occurs from May to December, so the predictions obtained at the end of the calculation are predictions for the 2022 milling period. The data are in the form of data production of granulated sugar obtained from the Candi Baru Sugar Factory. The required data are in Table 1.

TABLE 1. Data variable

Variable	Description
X	Granulated sugar production (Tons)

T The sugar production data is sorted, then arranged by category using frequency distribution and presented in tables. The first step is to find the range of granulated sugar production data. Range data is obtained by finding the difference between the largest and smallest data values. Based on the sugar production data, the largest data value is 7281.1 tons, and the smallest data is 262 tons, so the range of granulated sugar production data is

$$R = 7281.1 - 262 = 7019.1.$$

The range that has been obtained is used to find class intervals with Equation (2) as follows:

$$i = \frac{R}{4} = \frac{7019.1}{4} = 1754.8 \approx 1755.$$

The length of class intervals obtained can be used to form class intervals. The class interval will contain all the smallest to largest data that has been partitioned into four classes, with each class having a class interval length of I [22]. So that state categories can be formed, as in Table 2, and Table 2 is used to classify each data according to the state variable category in Table 3.

TABLE 2. State category

State	Description	Range
1	Drastically decrease	$262.0 - 2016.9$
2	Decrease	$2017.0 - 3771.9$
3	Increase	$3772.0 - 5526.9$
4	Drastically increased	$5527.0 - 7281.9$

TABLE 3. Sugar production data classification

Data every month		Classification	Data every month		Classification	Data every month		Classification	Data every month		Classification
May-2010	1630.1	1	Oct-2012	7222.1	4	Aug-2015	6736.5	4	Sep-2018	6943.9	4
Jun-2010	3642.9	2	Nov-2012	2035.8	2	Sep-2015	5995.4	4	Oct-2018	5219.6	3
Jul-2010	4044.7	3	May-2013	383.7	1	Oct-2015	6879.7	4	May-2019	3431.6	2
Aug-2010	4430.9	3	Jun-2013	2012.9	1	Nov-2015	2269.5	2	Jun-2019	3385.1	2
Sep-2010	2605.4	2	Jul-2013	4401.1	3	Jun-2016	2434.5	2	Jul-2019	6866.3	4
Oct-2010	4276.8	3	Aug-2013	3012.2	2	Jul-2016	2749.2	2	Aug-2019	5746.5	4
Nov-2010	3814.2	3	Sep-2013	5540.5	4	Aug-2016	5263.0	3	Sep-2019	6807.3	4
Des-2010	1112.3	1	Oct-2013	5621.6	4	Sep-2016	4811.9	3	Oct-2019	3763.2	2
May-2011	2859.7	2	Nov-2013	5866.1	4	Oct-2016	5420.0	3	Jun-2020	3390.9	2
Jun-2011	4531.1	3	Des-2013	3985.6	3	Nov-2016	5032.3	3	Jul-2020	5289.2	3
Jul-2011	4935.1	3	May-2014	946.4	1	Des-2016	4408.1	3	Aug-2020	5735.4	4
Aug-2011	4562.0	3	Jun-2014	4702.9	3	May-2017	1218.2	1	Sep-2020	5746.1	4
Sep-2011	3480.5	2	Jul-2014	4044.2	3	Jun-2017	3397.7	2	Oct-2020	2038.4	2
Oct-2011	7281.1	4	Aug-2014	4790.2	3	Jul-2017	6308.1	4	May-2021	529.8	1
Nov-2011	786.1	1	Sep-2014	6246.7	4	Aug-2017	6373.8	4	Jun-2021	5387.3	3
May-2012	1589.2	1	Oct-2014	5936.9	4	Sep-2017	5746.6	4	Jul-2021	4053.8	3
Jun-2012	4829.5	3	Nov-2014	4657.8	3	May-2018	3201.2	2	Aug-2021	5274.0	3
Jul-2012	5978.3	4	May-2015	262.0	1	Jun-2018	3162.4	2	Sep-2021	5212.6	3
Aug-2012	3982.6	3	Jun-2015	5457.7	3	Jul-2018	4478.2	3	Oct-2021	3613.6	2
Sep-2012	6695.8	4	Jul-2015	3933.1	3	Aug-2018	5557.1	4			

The following process is the preparation of the transition matrix obtained from the state transitions in Table 3. The transition matrix formed is used to form a one-step transition matrix to get an overview of the relationship between each state from the sugar production data. From Table 3, a transition matrix can be formed where each element contains the number of state transfers in each data sequence.

$$X = \begin{bmatrix} 2 & 3 & 5 & 0 \\ 2 & 5 & 6 & 4 \\ 4 & 5 & 14 & 6 \\ 1 & 5 & 4 & 12 \end{bmatrix}$$

Elements in the X matrix indicate a state transfer for all states (i) to all states (j) in the sugar production data. Each element in the transition matrix is solved by Equation (3) to produce the one-step transition probability matrix below.

$$X = \begin{bmatrix} \frac{2}{10} & \frac{3}{10} & \frac{5}{10} & \frac{0}{10} \\ \frac{2}{17} & \frac{5}{17} & \frac{6}{17} & \frac{4}{17} \\ \frac{4}{29} & \frac{5}{29} & \frac{14}{29} & \frac{6}{29} \\ \frac{1}{22} & \frac{5}{22} & \frac{4}{22} & \frac{12}{22} \end{bmatrix} = \begin{bmatrix} 0.20 & 0.30 & 0.50 & 0 \\ 0.12 & 0.29 & 0.35 & 0.24 \\ 0.14 & 0.17 & 0.48 & 0.21 \\ 0.05 & 0.22 & 0.18 & 0.55 \end{bmatrix}$$

From each one-step transition matrix that has been formed, it can be described in terms of the relationship between sugar production states as Figure 2 below.

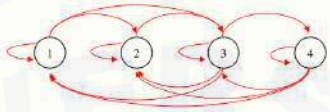


FIGURE 2. Relationship between sugar production state

Based on the illustration of the relationship between sugar production states shows a relationship that is not mutually exclusive, so other conditions influence the probability of each state.

The process is continued by looking for probabilities with n-step transitions; researchers use the help of QM for Windows software to get probabilities in each n-step until they reach steady state conditions. In this study, a dataset with the name of granulated sugar production will be created, and the number of states that will be used is four. Press "OK" after everything is in order. The initial state vector used in this study is $v^0 = [0.25 \quad 0.25 \quad 0.25 \quad 0.25]$, so that the sugar production dataset template is obtained, which contains the one-step transition matrix elements of granulated sugar production, as shown in Figure 3 below.

Produksi gula pasir

	Initial	State 1	State 2	State 3	State 4
State 1	,25	,2	,3	,5	0
State 2	,25	,12	,29	,35	,24
State 3	,25	,14	,17	,48	,21
State 4	,25	,05	,22	,18	,55

FIGURE 3 Sugar production dataset

Based on the data template in Figure 3, using the "number of transition" tool, then press "run" so that each iteration will produce an output of a transition matrix, ending probability (given initial)/state vector/v^n and steady-state probability. The transition of the granulated sugar production dataset is shown in Figure 4 below

Number of transitions: 1

Markov Analysis Results

Produksi gula pasir solution

	State 1	State 2	State 3	State 4
State 1	,2	,3	,5	0
State 2	,12	,29	,35	,24
State 3	,14	,17	,48	,21
State 4	,05	,22	,18	,55
Ending probability (given initial)	,13	,25	,38	,25
Steady State probability	,12	,23	,37	,29

(a)

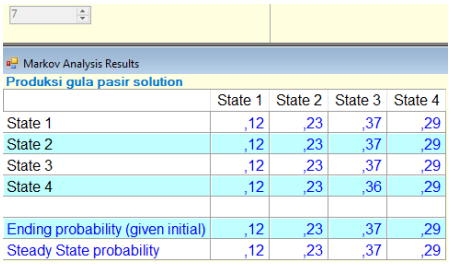
2

Markov Analysis Results

Produksi gula pasir solution

	State 1	State 2	State 3	State 4
State 1	,15	,23	,45	,18
State 2	,12	,23	,37	,28
State 3	,13	,22	,4	,26
State 4	,09	,23	,29	,39
Ending probability (given initial)	,12	,23	,38	,28
Steady State probability	,12	,23	,37	,29

(b)

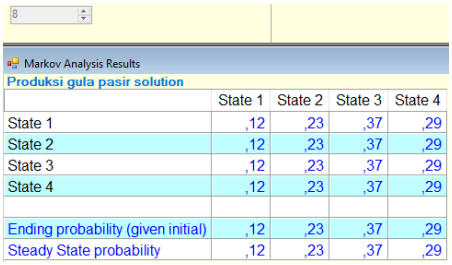


Markov Analysis Results

Produksi gula pasir solution

	State 1	State 2	State 3	State 4
State 1	,12	,23	,37	,29
State 2	,12	,23	,37	,29
State 3	,12	,23	,37	,29
State 4	,12	,23	,36	,29
Ending probability (given initial)	,12	,23	,37	,29
Steady State probability	,12	,23	,37	,29

(c)



Markov Analysis Results

Produksi gula pasir solution

	State 1	State 2	State 3	State 4
State 1	,12	,23	,37	,29
State 2	,12	,23	,37	,29
State 3	,12	,23	,37	,29
State 4	,12	,23	,37	,29
Ending probability (given initial)	,12	,23	,37	,29
Steady State probability	,12	,23	,37	,29

(d)

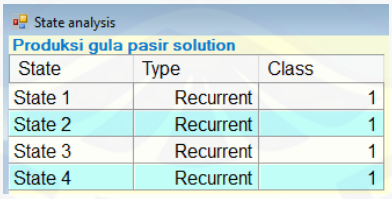
FIGURE 4. (a) first transition, (b) second transition, (c) seventh transition, (d) eighth transition.

Based on Figure 4 (d), sugar production reached a stable condition in the eighth iteration. Each dataset transition of each variable produces an ending probability/state vector, which is the probability of each transition which is presented in Table 5 below.

TABLE 5. Sugar production probability

Probability	State 1	State 2	State 3	State 4
$v^1 =$	0.13	0.25	0.38	0.25
$v^2 =$	0.12	0.23	0.38	0.28
$v^3 =$	0.12	0.23	0.39	0.29
$v^4 =$	0.12	0.23	0.38	0.28
$v^5 =$	0.12	0.23	0.37	0.29
$v^6 =$	0.12	0.23	0.37	0.29
$v^7 =$	0.12	0.23	0.37	0.29
$v^8 =$	0.12	0.23	0.37	0.29

Table 5 contains the production probabilities for granulated sugar during eight transitions, indicating that the largest probability is in state 3. Based on classified sugar production data, most state transitions ended in state 3. In QM for Windows, the state of granulated sugar production can be analyzed by the tool "State analysis." The state of the sugar production system is classified in Table 5.



State analysis

Produksi gula pasir solution

State	Type	Class
State 1	Recurrent	1
State 2	Recurrent	1
State 3	Recurrent	1
State 4	Recurrent	1

FIGURE 5. Sugar production state analysis

Figure 5 shows that State 1 to state 4 in sugar production fulfills the steady-state ergodic properties so that through Equation (7), the steady-state probability of granulated sugar production can be seen in Table 6.

TABLE 6. Steady-state probability for sugar production

	π_1	π_2	π_3	π_4
Sugar production	0.12	0.23	0.37	0.29

Table 6 is a table that shows the steady-state probability of sugar production. It is found that the long-term probability of granulated sugar production in a drastically decreasing condition is $\pi_1 = 0.12$, in a down condition $\pi_2 = 0.23$, in an up condition $\pi_3 = 0.37$, and a drastically up condition $\pi_4 = 0.29$. The steady-state probability shows a fixed

probability after performing the -step transition process; the steady-state probability can change if additional data is added and the Markov Chain process is carried out again. Based on Table 5, the prediction of granulated sugar production is obtained by multiplying each state vector by 100% so that the prediction of sugar production can be seen in Figure 6.

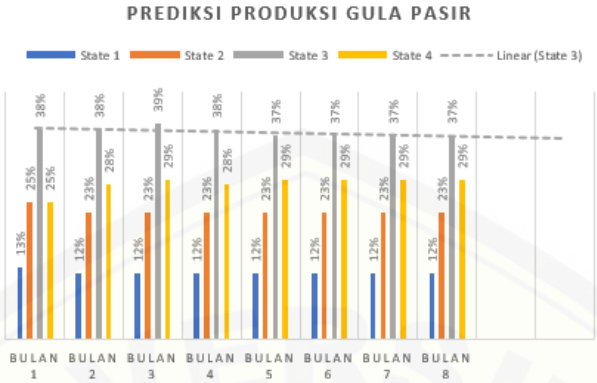


FIGURE 6. Sugar production prediction

Based on the picture above, it is found that production predictions from May to December will be in state 1 (down drastically) of 12% - 13%. The prediction of sugar production from May to December will be in state 2 (down) at 23% - 25%. Sugar production from May to December is predicted to be in state 3 (up) at 3772 – 5526.9 ton) with 37% - 38%. Sugar production from May to December is predicted to be in state 4 (a drastic increase) by 25 – 29%. The explanation above shows that the largest prediction is in state 3, so for the months of May to December 2022, sugar production is predicted to be in an upward condition. After December, sugar production will be stable at state three or an increasing condition.

CONCLUSION

Based on the results and discussion of Markov Chain predictions on the four data variables, it was successfully carried out with the help of QM for Windows. The most significant prediction is that sugar production for May to December will be in increasing condition (3772 – 5526.9 tons) with a percentage level of 37% - 39%

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