Evaluation of Combined Sewer Network Design Using GIs and Multi Criteria Decision Making (MCDM)

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Abstract

In this Research Geometric network modeled for combined sewer network pipe design were establish for AL-Nahrain University site by Arc map and GIS tools which is built within a feature dataset in the geodatabase. The geometric networks consist of lines and points which refer to the pips and junctions respectively. Data were collected for manholes location, flow direction, slop and elevations. Many influencing features were used in multi criteria decision making (MCDM) vie Super decision 2.0.8 software which be selected to fix the problem and find the alternative for two sewer networks. The first sewer network (A) considered the existing one and the second was the alternative one (B) , Bentley sewer Cad V8 have the ability to work with ArcGIS program as a part of it by export data as shape file from GIS then by scenario report form program that exam the part of network and find the alternative . The purpose of this research was to use this data GIS model, and developed it in future event by predicting some function like rainfall amount or adding population increasing density represent by both student and employers. As a result using (ANP) analysis this method allow to make consideration alternative we found the network(A) need to add some routs depending in the amount of person daily consumption with the amount of rain fall Intensity for the next years., judgment based on expert advice is obtained through pair-wise comparisons. Afterwards, the corresponding matrix is established, and sanity of the comparisons is checked by super decision software. Finally Existing network (A) shows highest benefit score and efficiency in this time for steady case depends on two criteria coast and optimum flow for person consumption.

Keywords: Geometric network, GIS, Sewer Cad, MCDM, super decision2.0.8 software, ANP.

1. Introduction

Geographic Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) techniques is a world acknowledged efficient way for solving problem and find alternatives. Integration of the capabilities of these tools is essential to the feasibility of reaching a final result [1].powerful of tools used to evaluate sewer network [4].topology was the arrangement in which points, lines and polygon features share equivalent geometry [1].Sewerage system is composed of various sewer lines terminating at the junction of a number sewer pipe line. [5] Geometric networks offer a way to model common networks, water flow, manholes capacity, and pipes diameter can be modeled and analyzed using a geometric network [3].map which used as raster image in GIS determine general location of area and survey Detail [6]. Sewer CAD is an extremely powerful program for the design and analysis of gravity flow and pressure flow through pipe networks and pumping stations. The program can be run in AutoCAD mode, giving you all the power of AutoCAD's capabilities, or in Stand-Alone mode utilizing our own graphical interface.[11]Spatial multi-criteria decision problems involve a set of geographically defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria .In contrast to the conventional multi-criteria evaluation [7].Analytical network process (ANP) is the most commonly used GIS-based on multi criteria evaluation procedures [8]. The principle of comparative judgments requires assessments of pair-wise comparisons (on a scale of relative importance) of the elements within a given level, with respect to their parent in the next-higher level. In general, this comparison takes the form: "How important is element 1 when compared to element 2 with respect to the element above [2] fuzzy theory ANP procedure allows decision maker evaluation in which GIS used to calculate the local scores of each alternative as a cell (raster format) or a polygon (vector format)[8].

2. Study Area and Materials Used

In this paper the study area will be recognized and include as a large sector, it was cover 60% from the total area of al Nahrain university which districts in the middle south of Baghdad city/Iraq it is denoted by Baghdad university from west ,AL-Jaderiya region from the north east and Tigris river from the west as it illustrate in figure (1) .so it is easy to obtain topographic , satellite, and CAD maps for implementation the methods of the optimum flow for its sanitary network, pipe directions ,slop , diameters , manholes locations in addition to the nature of the region that is characterized by high population density.

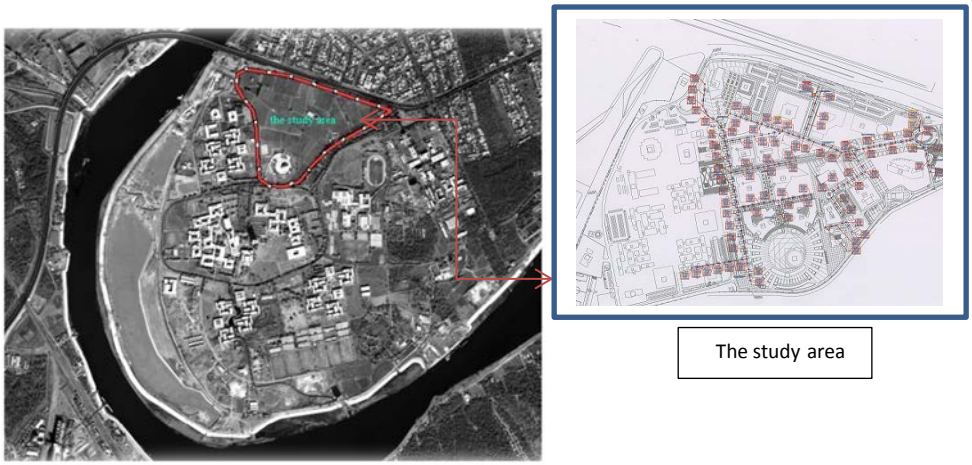


Figure 1: The Sector of Field Study Area [Aerial Photo 2003], Auto Cad map

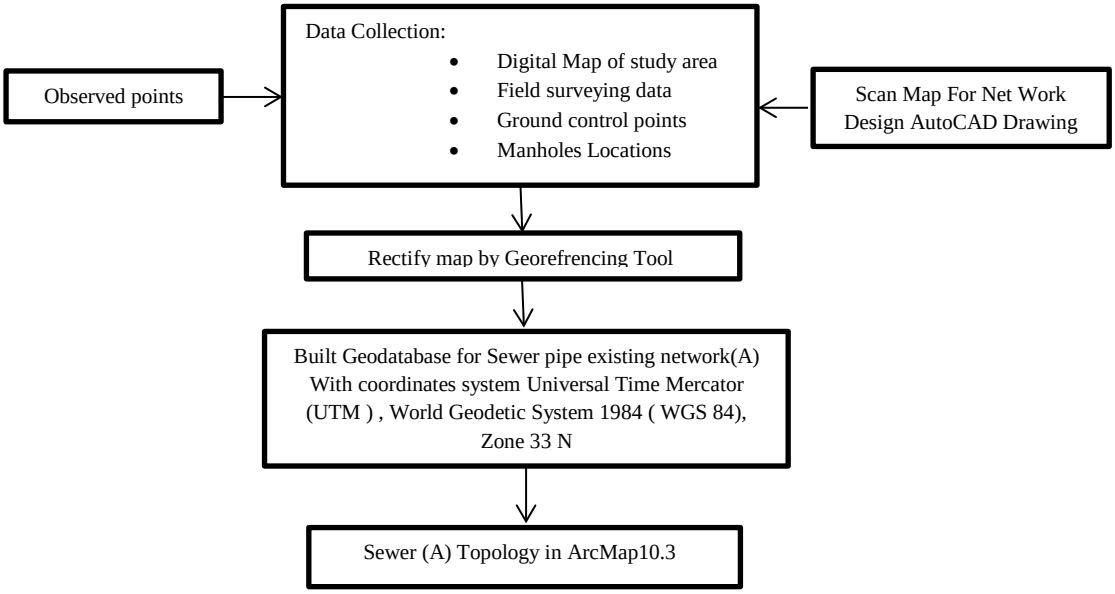
3 Work Methodology

Integration of hybrid Geographical Information System (GIS) processes and multi-criteria decision-making (MCDM) theories are employed to investigate interrelationships among the criteria to find problem solution. Analytic network process (ANP) principles are used to deal with systematic interactions. We considered several factors such as optimum flow, coast, and rainfall intensity and population density characteristics in the decision-making procedure for a sustainable sewer network. In GIS by using Arc map (10.3) this software used to determine the appropriate of the existing sewer network (A). Geometric network and network utility Arc catalog tools showing by attribute table that was useful and reliable analysis and mapping.

Several computations are selected for this study in Attribute table such as population rat density , water consumption, digital elevation model for the selected area , existing network design, rain fall intensity and water flow direction depending in pipe slop rule design (manning rule) for which pipes diameter ,maximum slop ,pipe length ,roughness pipe material coefficient. The flow chart for the steps of the paper stages methodology and methods selection, programing are illustrate in figure (2).

3.1 GIS Functions In Sewer Network

Powerful tools in Arc Map GIS 10.3 used to get Georefrencing sewer, storm water, topology, geometric network and network analysis utility .First model which be acquired by scan AutoCAD map tiff. Extension by rectify Georefrencing this map for four ground control points selected in map's corner, Auto adjustment for acceptable root mean square error computed by first order polynomial method as it shown in table (1) .also ensure map's unit with coordinates system Universal Time Mercator (UTM),World Geodetic System 1984 (WGS 84), Zone 33 N as it illustrate in figure(3) below.



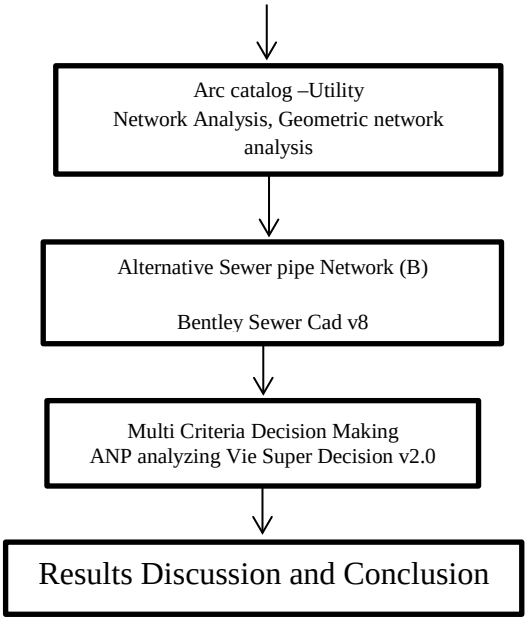


Figure 1: Flow Chart Illustrating the Methodology of the processing Design

Table (1): Auto adgjustment Root mean square error in Arc map GIS

Point	X source	Y source	X map	Y map	Resediual
1	442694.871523	3382575.972132	442698.730050	3382574.042868	0.0001
2	441969.468423	3382757.322907	441973.326950	3382755.393643	0.0001
3	441670.432569	3382386.904303	441674.291097	3382384.975039	0.0001
4	442075.577912	3382130.312194	442079.436446	3382128.382984	0.0001

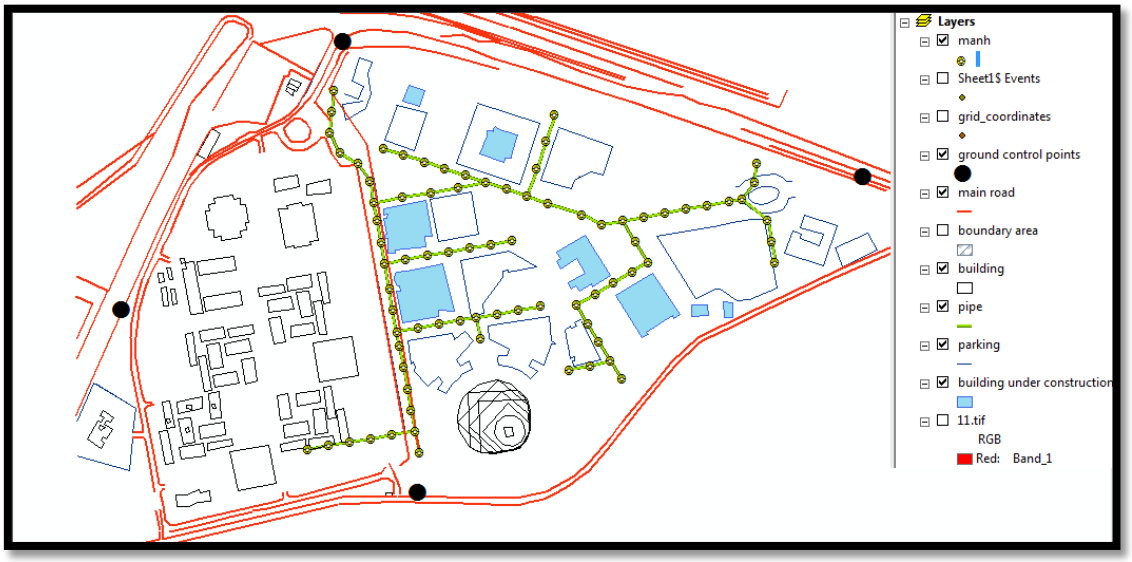


Figure 3: The wire frame map for the study area and the existing sewer network (A)

Model for digital elevation was establish vie Detail survey, 1800 points selected in the study area to evaluate the leveling grid Interpolation it was picked up by differential GPS as it illustrate in figure (4). Topology for the existing network establish to check pipes endpoint, loops closed line etc.[16].As it seen in figure (5). Sewer network establish with attribute table contain the specifications of design criteria pipes, manholes, etc.as it shown in figure (6).

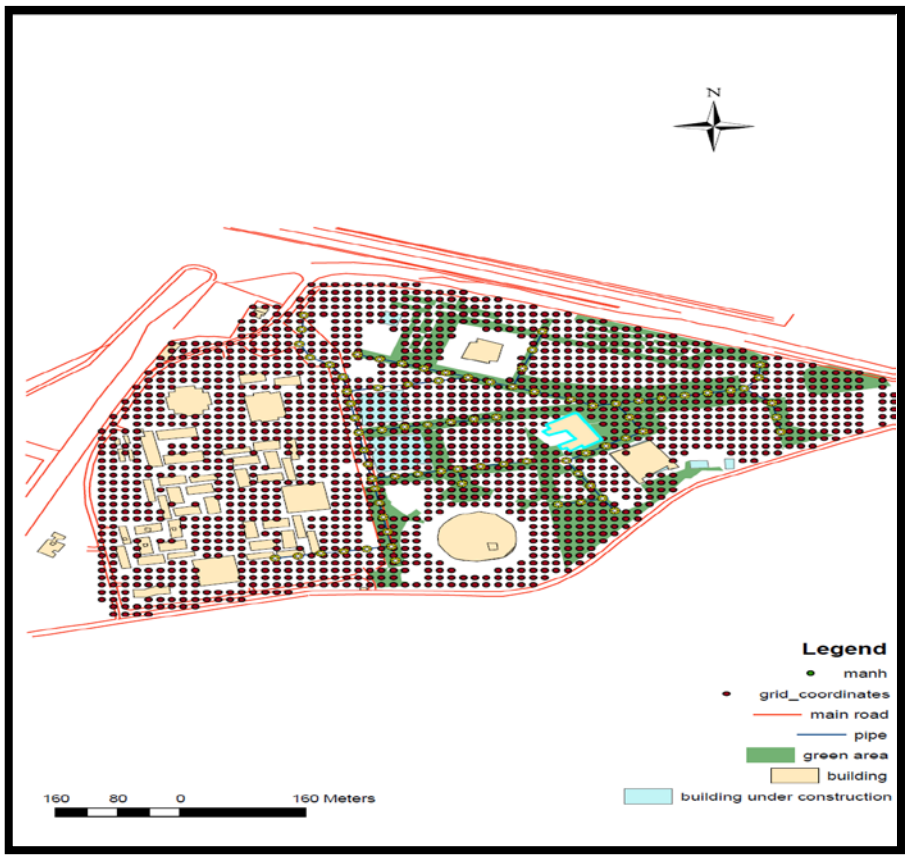


Figure 4: Grid interpolation of digital elevation model (DEM)

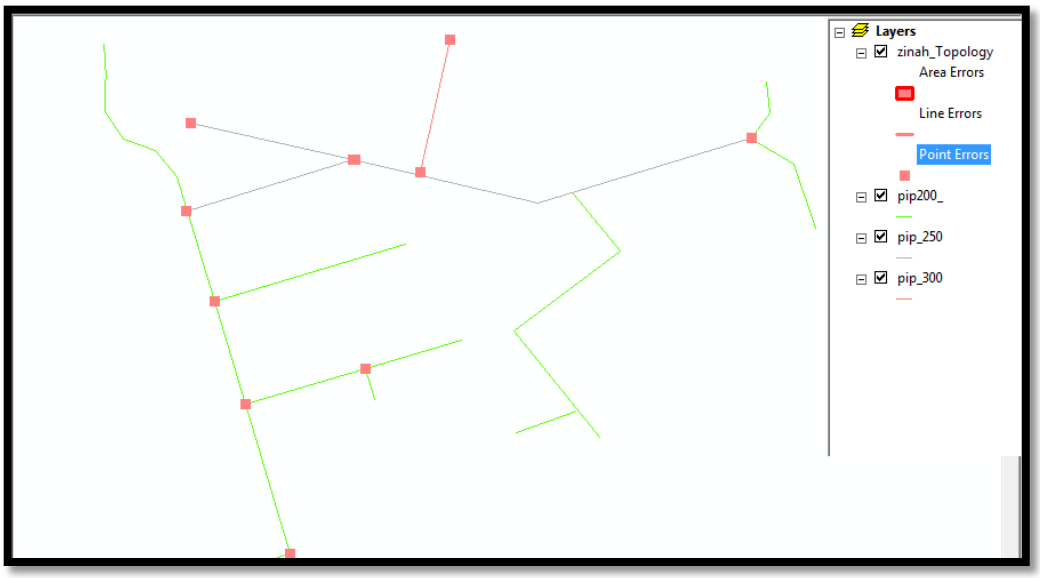


Figure 5: Error in network topology

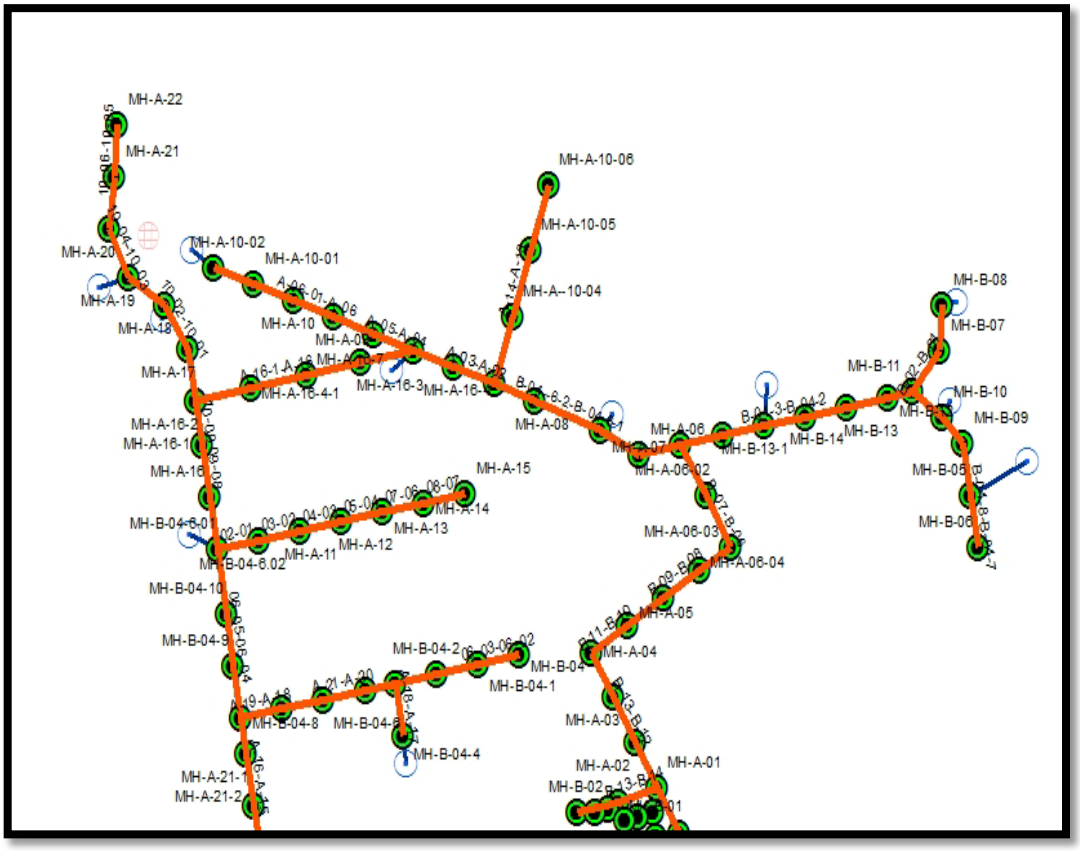


Figure 6: The Total Sewer Network Pip

After topology and According to the digital elevation model the flow direction on sewer network is display as it illustrate in figure (7).Also Junctions in which old sewer network are connected with Sewer (A) in the sector of college of science and number of employers and student in each building its influenced in daily consumption 45 L/day for educational institutions [10] as it illustrate in Table (2).

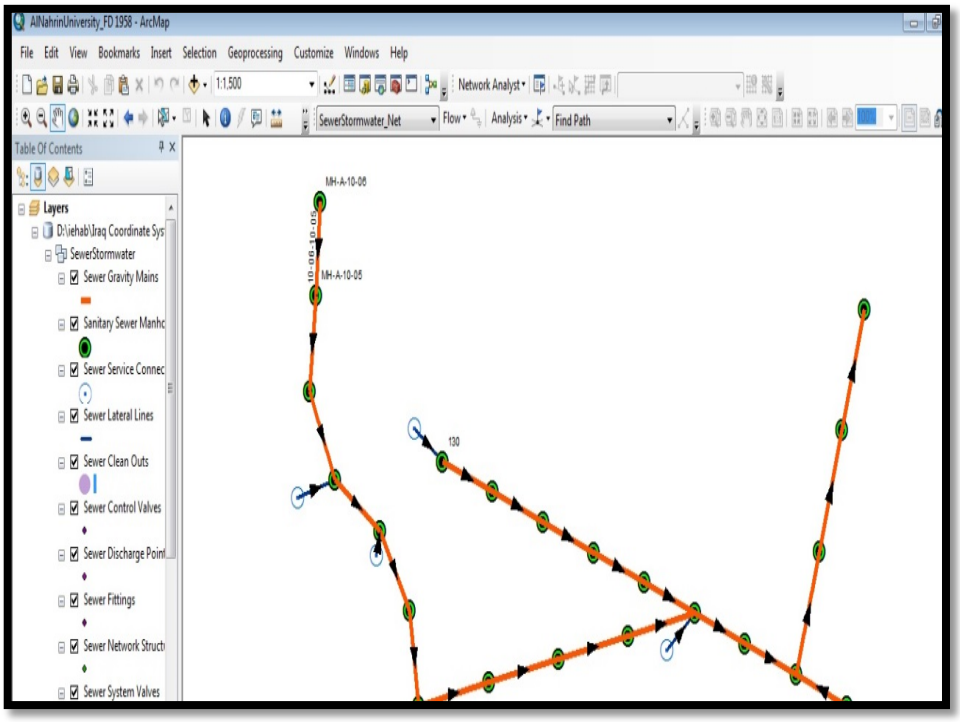


Figure 7: The Direction of Flow and Utility According To Network Analysis

Table (2): Population Density for Each Building In Sewer Net Work

Building Name	Manhole	NO Of Students	No Of employees
information technology college it	MH-A-06	140	30
head of it	MH-A-05	--	75
President of Al_Nahrain university	MH-B-10	--	753
Engineering consult bureau	MH-B-04-9	--	50
central library	MH-A-11	50 ~ 70	35
numbers of buildings (college of science)	MH-A-21-5	460	295

3.2 Design of Proposed (Alternative) Sewer Network (B)

Bentley Sewer CAD v8 allows you to construct a graphical representation of a pipe network containing information such as pipe data, pump data, loading, and infiltration. You have a choice of conveyance elements including circular pipes, arches, boxes and more. The advantage of this computer program is its ability to work with ArcGIS program as a part of it by export data as shape file from GIS to sewer Cad. The Sewer Cad computer program can integrate with the ArcGIS program and all its abilities of design and analysis can be used depending on information and shape files already existed in the GIS platform.[10].Many buildings will be establish and construct also the prediction of increasing capacity of student, employers, rain water intensity can be obtained so many parts will be consider in this work to find the alternative sewer network (B).Bentley sewer Cad v8 used to check the existing sewer network according to the input design data ,program have the capability of analysis with power full tools. Figure (8) shows the Sewer Cad V8i computer program interface in ArcGIS computer program as an integrated copy, though it can be used as a stand-alone computer program.

3.2.1 Steps of Analysis Design Alternative

Design of existing sewer network were analysis by three bases constrains, Physical Properties, Sanitary (Dry Weather) and Design Constraints [13].

Physical properties such as Gravity, Manhole and Outlet .for the inventory of the sewer network design are illustrated in Table (3)

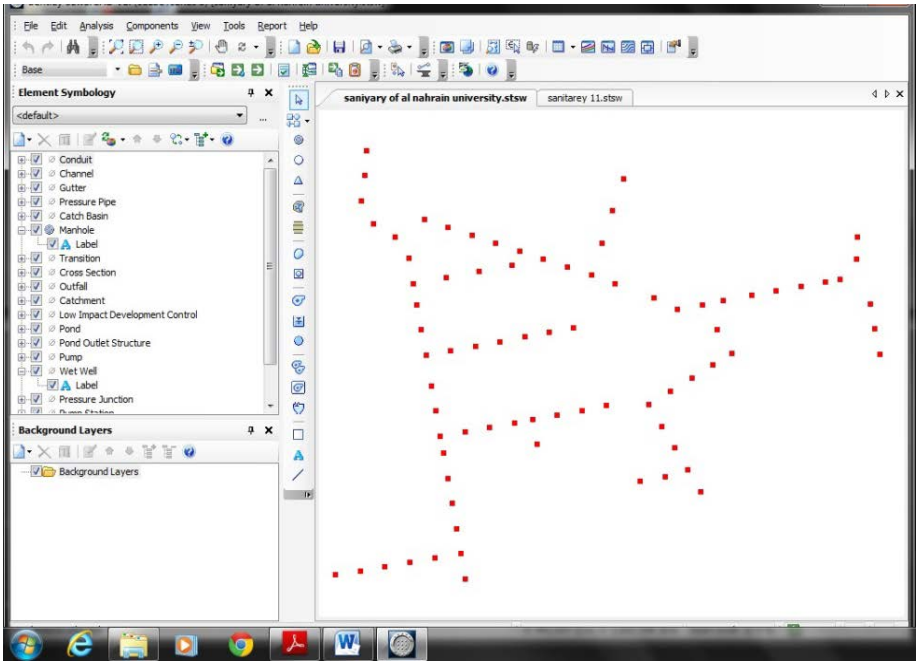


Figure 8: Sewer Network (Manholes Location)

Table (3): Project inventory of al_ Nahrain sanitary Network sts.w

Type	count no	
Manholes	79	
Conduit Description		Total length(m)
Circle - 200.0 mm	53	1643 m
Circle - 250.0 mm	19	573 m
Circle - 300.0 mm	5	135 m
Total Length	77	2,354 m

3.2.2 Rainfall Storm Water Design

Storm water rain fall intensity (mm/hr) effected for time duration (15, 30 and 60 minutes) for 25-years as shown in figure (9) [15]

3.2.3 Manning's Formula

Sewer hydraulic in circular section shape for steady – state, flow is computed manually for each manholes by equation (1) and Manning's equation (2). The last developed for analysis of flow in open channels, it is now widely used to analyze flow in both open channels and closed conduits [12].

$$Q = V * A \quad \text{…. (1)}$$

$$Q = A * \frac{1}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}} \quad \text{…. (2)}$$

$$V = \frac{1}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}} \quad \text{…. (3)}$$

$$S = (V * n * R^{\frac{2}{3}})^2 \quad \text{…. (4)}$$

$$D = (6.42 * Q * n / S^{\frac{1}{2}})^{\frac{3}{8}} \quad \text{…. (5)}$$

Where:

Q = volume flow (m^3/s) or (L/day)

A= cross sectional area of flow(m^2)

n = Manning's roughness coefficient (PVC pipe with circular shape) = 0.009-0.011

R = hydraulic radius A/P (m)

s = hydraulic gradient (m/m)

D= hydraulic diameter (m)

V = cross-sectional mean velocity (m/s)

P= wetted perimeter (m)

Flow was computed for each manhole then added in Flexible Base design depend on the average day demand and the occupied area. As shown in figure (9).

Gravity pipe Design which contain the minimum and maximum for velocity, cover, slope respectively. As illustrated on table (4) and figure (10).

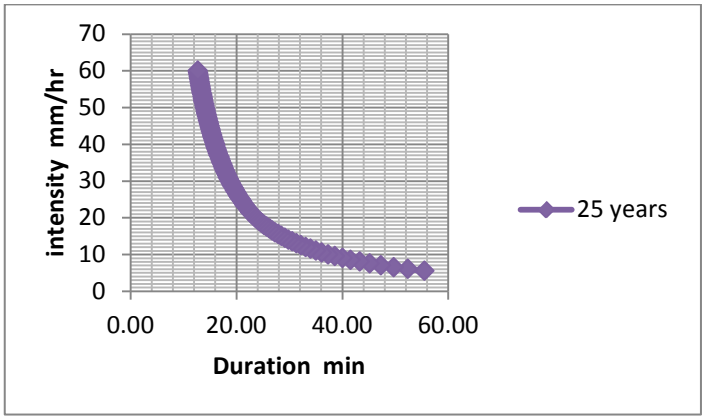


Figure 9: Intensity Rain fall for 25 years Baghdad [15]

Table (4): The Pip Gravity Design

	Minimum	Maximum	Unit
Velocity	0.6	3	m/s
Cover	1.5	6	M
Slope	0.005	0.15	m/m

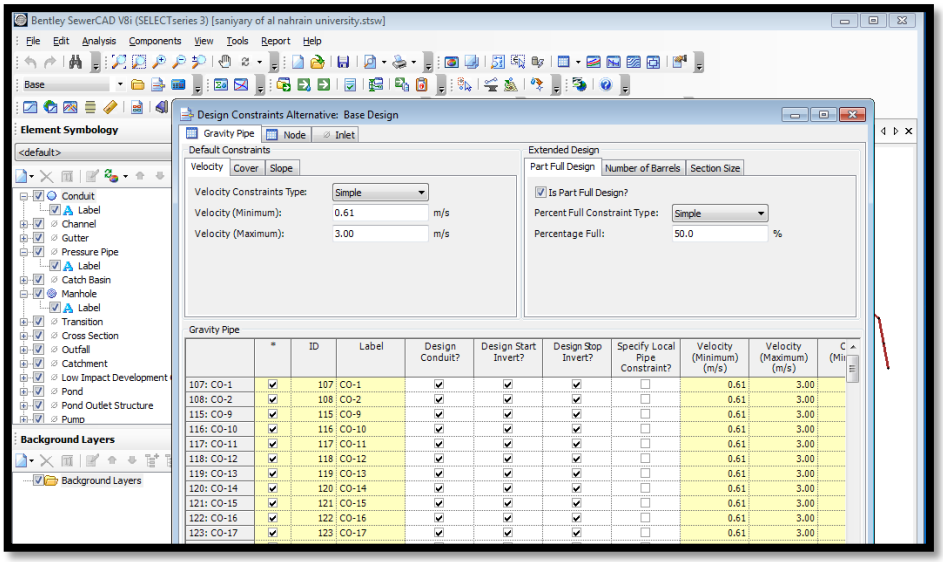


Figure 10: Design Constrain Alternative (sewer Cad V8)

3.2.4 Results Sewer Cad Report

Gravity pipe report and storm water intensity show the section pipe size, shape and length. And storm water graphic design all show by colorings alternative in some parts need to cumulative network assessment but the existing sewer network show the capability by total flow for each Manhole in steady case. The performance of sewer network show in components By coloring coding we choose area and flow as it illustrate in figure (11) and (12) below.

	Value <= (m²)	Color
0	580.0	0; 255; 0
1	1,060.0	0; 255; 2...
2	1,540.0	0; 0; 255
3	2,020.0	255; 0; 2...
4	2,500.0	255; 0; 0
*		

Figure 11: coloring coding for area

	Value <= (L/day)	Color
0	600.00	0; 255; 0
1	700.00	0; 255; 2...
2	800.00	0; 0; 255
3	900.00	255; 0; 2...
4	1,000.00	255; 0; 0
*		

Figure 12 : coloring coding for flow

4 Multi Criteria Super Decision Making

After preparing the most effected criteria both in GIS and Sewer Cad another selecting Approach are enter from judgment questioner to evaluated this sewer network, ANP is the most suitable MCDM technique for solving this problem .Pairwise comparison matrix (cluster) introduced by super Decision Making program V2.8.0, this model is formulated and applied to select examine and solving the problem. Comparison between Two sewers networks establish to find the most suitable one depends on criteria.

4.1 Build ANP Model

The next step is to build the ANP analytic network process decision model for both GIS and sewer Cad selected problems. In the Super Decisions model is made up of clusters, nodes and links. Below is a
Screenshot of the sewer choice hierarchy as it illustrate in the figure (13).

4.2 Pair Wise Comparison Matrix

Several modes used in this section for pairwise comparison Fundamentals of
Decision Making and Priority Theory [14] gives more details about the mathematic of the pairwise comparison matrix. The goal in this study is to select the optimum sewer network for the case study area in which parent node of the criteria and they comprise one to each other in ANP model .The criteria will be pairwise compared with respect to the goal. The pairwise comparison judgments are made using the Fundamental Scale of the Analytic Network Process and the judgments importance are arranged in a matrix as it illustrate in Table (5) below**.** Matrix Comparison Mode as shown in the Super Decisions Software in figure (14).
Note that the priorities in the Results panel are the same as those given mathematically above for the comparison matrix. The inconsistency is also given. In this instance it is .06644 which is

satisfactory; the inconsistency should be less than 0.10.As it illustrate in figure (15),(16) and (17).

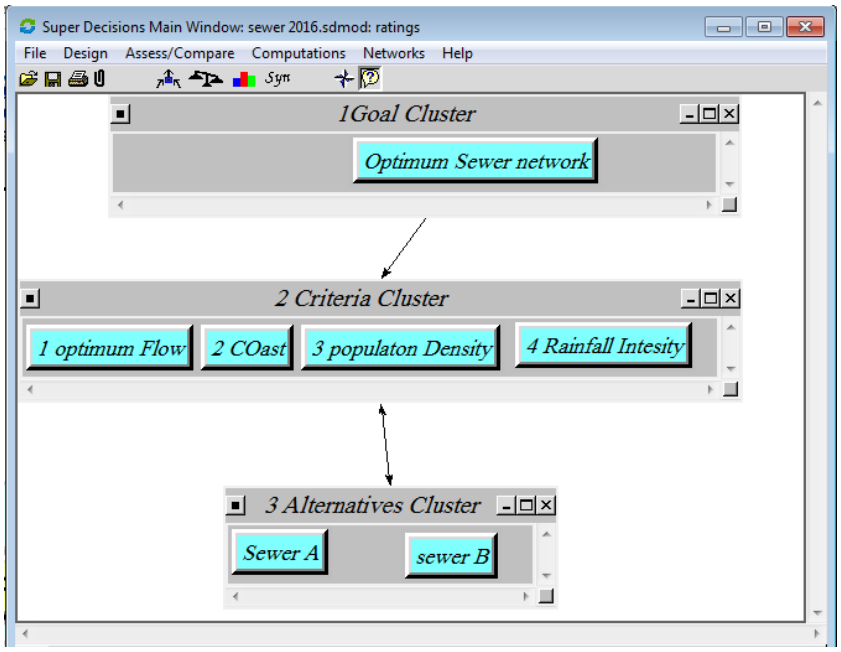


Figure 13: ANP Model

Table (5): Pair Wise Comparison Matrix

GOAL	Coast	Rain Fall	Population Density	Optimum Flow
Coast	**1**	**1/5**	**1/3**	**1/2**
Optimum Flow	**5**	**1**	**3**	**2/3**
Rain Fall	**3**	**1/3**	**1**	**1/3**
Population Density	**2**	**3/2**	**3**	**1**

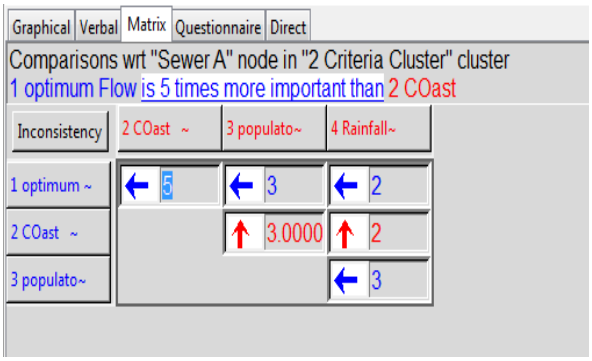


Figure 14: Sewer A Matrix comparison

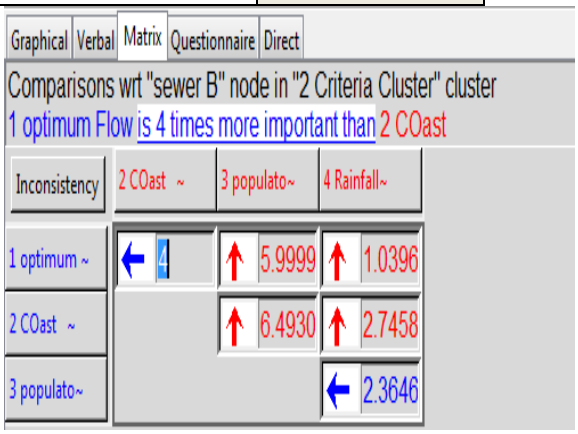


Figure 16: sewer B Matrix Comparison

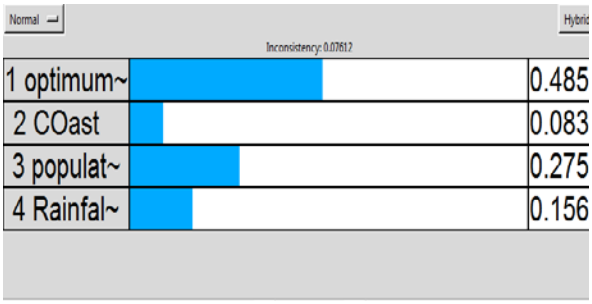


Figure 15: Inconsistency Result

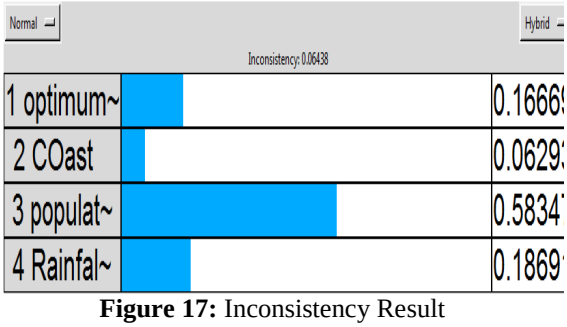
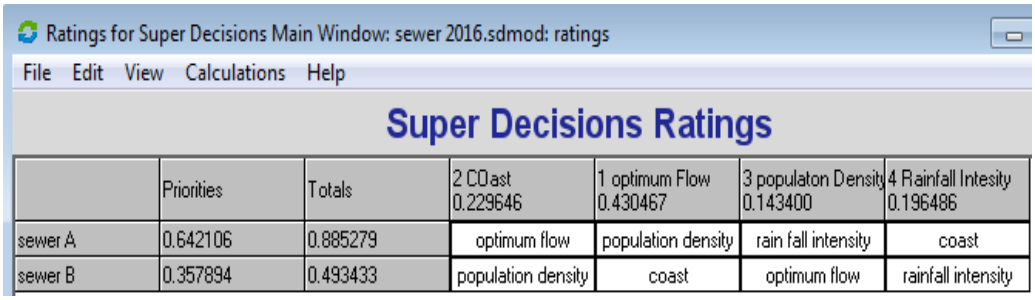


Figure 17: Inconsistency Result

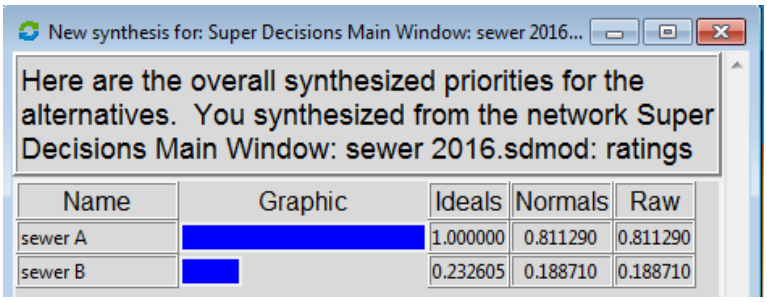
4.3 Rating

Judging the importance of criteria (weighting the criteria) by scoring and evaluated alternatives.in rating model standard are established for pair wise comparison and alternatives are rated one at time against them as it illustrate in figure (18)Priorities can also be displayed with the calculation synthesize command .the whole synthesize of all ANP model shown below in figure (19).



	Priorities	Totals	2 COast 0.229646	1 optimum Flow 0.430467	3 populaton Density 0.143400	4 Rainfall Intesity 0.196486
sewer A	0.642106	0.885279	optimum flow	population density	rain fall intensity	coast
sewer B	0.357894	0.493433	population density	coast	optimum flow	rainfall intensity

Figure 18: Super Decision Rating



Name	Graphic	Ideals	Normals	Raw
sewer A		1.000000	0.811290	0.811290
sewer B		0.232605	0.188710	0.188710

Figure 19: Overall synthesized Priorities

4.4 Results and Conclusions

In this paper GIS analysis and MCDM are an ideal performing Process by selecting utility GIS tools and assessment computer programs such as sewer Cad which was used to evaluate the existing sewer cad and give feedback alternatives. This approach integrates the capabilities of GIS and MCDM (ANP) to provide the more effected subjects Criteria in Engineering Designs .the biggest variation evaluation happened in Super Decision software in which analytic network process found that sewer (A) existing one was more satisfactory and show efficiency than alternative one sewer (B) in the steady case which the minimum sewer network coast criteria effected , but for future demand we need to add some parts such as pipes if add some buildings by increasing the population density refers to students numbers and employs in this case optimum flow and population density criteria were be effective .

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تقييم شبكة الصرف الصحي المشتركة باستخدام نظم المعلومات الجغرافي وصانع القرار متعدد المعاملات

زينة عادل نجيب
قسم الهندسة المدنية
كلية الهندسة / جامعة النهرين

الخلاصة

في هذا البحث تم اعتماد تصميم شبكة التصريف الهندسية لمياه المجاري والامطار للابنية المضافة والابنية قيد الانشاء لموقع جامعة النهرين بأستخدام أدوات نظام المعلومات الجغرافي والتي تم بناءها بأستخدام قاعدة بيانات الجيؤيد وتتألف الشبكة من خطوط ونقاط والتي تشير الى أنابيب التصريف ونقاط التقاطع بالتتابع . البيانات التي تم جمعها من مواقع المنهولات هي أتجاه التصريف ,الميل,والمناسيب . العديد من المحددات المؤثرة تم اعتمادها بأستخدام برنامج افضل صانع قرار والذي اختير لتثبيت المعوقات وأيجاد البدائل للشبكة الحالية والشبكة البديلة المستقبلية. بالاعتماد على التحليل الشبكي للمعايير وهي افضل تصريف,الكلفة ,مقدار شدة الامطار,الكثافة السكانية حيث وجد ان الشبكة الحالية جيدة وكفوءة في الحالة الثابتة بالاعتماد على معياري الكلفة وأفضل تصريف اشارة الى الاستهلاك اليومي للفرد .