Transportation Network Design Using GIS–Based DSS: Baghdad Metro Case Study

IBRAHIM A. HAMMADI
College of Computing and Information Technology
Arab Academy for Science and Technology and Maritime Transport
Alexandria, Abu Qir
EGYPT

SALEH MESBAH
Information Technology Department
Alexandria University
Sharq Av., Abu Qir Street
EGYPT

KHALED MAHAR
College of Computing and Information Technology
Arab Academy for Science and Technology and Maritime Transport
Alexandria, Abu Qir
EGYPT

Abstract: - Transportation design concepts and standards are adopted to build a Geographic Information System Model to design a new transportation modal. Socioeconomic and spatial data are utilized to identify components of the network; junctions and edges. Potential network elements and their associated attributes are subjected to Analytic Hierarchy Process (AHP) to rank alternatives. Some necessary assumptions to pairwise criteria are carried out to find their eigenvector. A tree branches concept is simulated to propagate routing and building the whole transportation network system. Metro system modal in Baghdad city is presented as a research case study.

Key-words: - Transportation Network Design; Comprehensive Transportation Study; Geodatabase; AHP, Metro Routing Model, Central Business District (CBD), and Route Branches.

1 Introduction
Modeling spatial related entities as components of targeted network is the main aim of this research. Optimizing the connections between them according to proposed criteria is the next step to find out the best network schema which fulfills the pre adopted evaluation criterion. This research focuses on transportation network, specifically metro (underground) as transportation modal. Metro system can achieve significant participates in urban transportation modes. As a comparison with other single lane modes, it can hold more than 50% of passengers per hour capacity [1]. The spatial extent (study zone) is Baghdad city urban area; there are some serious steps to support its transportation modals with metro system. Comprehensive Transportation Study (CTS) were completed in 1980’s with forecasting scope up to 2015.

The paper aims to present a new approach of transportation network design based on capabilities of Geographic Information System (GIS) and Decision Support Systems (DSS). Geodatabase building, visualization, and spatial analysis are the main contribution of GIS. The implementation of AHP as a DSS tool facilitated the network elements ranking. New software is developed to map (read and update) data from geodatabase and subject it to AHP steps. The software is AHP Network Design using GIS (AHPNDGIS). It builds KML format files for the output routes also.
2 literature Review

The GIS components are geographic core idea, technology, data, specialty field, procedures and methods, and Geovisualization [2]. They explain the diversity of GIS applications and methods.

Spatial network modeling, analysis and design were performed using GIS capabilities [3], [4]. The web based GIS provided interactive mapping and spatial analysis. Systems like online crash information [5] and collaborative transportation planning [6] were based on GIS capabilities.

Long term planning of highways and transit systems is based on models like Trip generation Trip distribution, and Population model [7]. Transportation and socioeconomic data are involved in planning phases. Metro system has its significant characteristics as a mass transit modal [8]. They reflect some specialized trends and standards like spacing between stations (800 -1200 m) [9].

The GIS-based (spatial) decision support systems (SDSS) enhanced the efficiency of urban planning [10] and linear engineering structures design [11]. It merges GIS visualization and analysis with DSS tools. SDSS provides spatial relations and structures and analytical techniques for spatial problems. Major concern is required to find an appropriate balance between the scope and extent of the problem and DSS tools [12].

AHP was used widely to support SDSS problems which require an optimization of multi criteria or multi objectives. Problems of selecting optimal routes according to predefined criteria can be solved in AHP implementation [13] and [14].

A previous study proposed metro network design for Baghdad included 36 stations [15]. It was consisted of two lines which intersected in CBD. The total length of the system was 32 km and the average spacing between stations was 850 meters.

3 Methodology

The main elements of the transportation network are nodes (junctions) and links (edges). Stations and intersections are represented by the junctions. The edges are direct representation of the real world entities of roads, streets, highways (Fig. 1). DSS phases are adopted to assign the research phases as shown in Fig.2.

3.1 Intelligence phase

Data are collected in this phase from different sources and with various formats. The compatibility of data is achieved by reflecting them into geodatabase. Spatially referenced entities are drawn in feature classes and joined with tabular data.

![Node (Junction)](image1)

![Link (Edge)](image2)

Fig.1 A simple directed network (N = 7, L = 11)

3.2 Design phase

Potential junctions of network are assigned based on predefined criterion. Hence connections between them are considered as potential edges. The collected data are adjusted to reflect the attributes of junctions and edges. Criteria based on socioeconomic and geometric attributes are proposed in weighing junctions. The same approach is used to specify edge’s attributes (criteria). In both cases AHP nine-scale ranking is implemented to pairwise the attributes and to rank entities. AHPNDGIS software is dedicated to carry out the automation of data mapping and AHP implementation on all entities. It is designed to adopt up to 10 criteria for each junction and edge.

3.2.1 Network components weighing:

The algorithm to apply AHP method on n number of alternatives according to m proposed criteria is:

1. Pairwise criteria (attributes); matrix of (m, m)
2. Assign normalized eigenvector value for criteria; matrix of (m, 1).
3. Reflect each attribute value into 9-scale AHP ranking.
4. Pairwise the n alternatives m times (according to each criterion).
5. Assign normalized eigenvector value for each alternative via each criterion; matrix of (n, m).
6. Multiply the (n, m) matrix by the (m, 1) matrix of the criteria eigenvector.
7. The (n, 1) resulted matrix represent the normalized weight of each alternative.

The outputs from the previous algorithm implementation are the weights of each junction and edge.

3.2.2 Targets assignment

Some of the potential junctions supposed to be targeted in network routing. As an example they can be main intersections in highway network or main stations in metro and railroad networks. The criteria to assign them depend on the data analysis and the
suggested network schema. After this step, each junction supposed to has one target.

### 3.2.3 Routes propagation:

From each junction, there is one virtual rout toward its target. The path is growing toward the best neighbor junction (higher weight) using the best connected edge (higher weight). A special method in AHPNDGIS is designated to assign each of these routes and their components. It handles the probability of falling in circulated routes. The route is powered to choose the next best path if it is going to circulation. The weight of each path (edge) is modified by proposed factor to attain propagation toward the target:

\[
D_{\text{EdgeW}} = \text{EdgW} \pm \frac{|D_s - D_e|}{D_s} \times \text{EdgW} \quad (1)
\]

*Where:*  
\(D_{\text{EdgeW}}\): edge weight according to the direction from the start point.  
\(\text{EdgW}\): edge weight according to the impact of the proposed criteria.  
\(D_s\): distance from start junction to target (main station).  
\(D_e\): distance from the end junction to target.  
+ : if \(D_s > D_e\)  
- : if \(D_s < D_e\)

### 3.2.4 Tree branches simulation:

A method in AHPNDGIS is designed to assign the number of routes which pass through each edge. The calculated number can be assigned as an attribute for the edge. Symbolizing that attribute in GIS software led to name it as Branch Degree (BD); higher in value is represented as thicker. Edges of zero BD value are neglected.

The effect of O:D between each successive junctions and the weight of the edge between them are used to calculate a new edge weight. It is the route branch weight (RBWeight) as in (2).

\[
\text{RBWeight} = \text{BD} \times \text{BW} \times \text{PTDAverage} \quad (2)
\]

*Where:*  
\(\text{RBWeight}\): Route Branch Weight.  
\(\text{BD}\): Branch Degree.  
\(\text{BW}\): Edge weight.  
\(\text{PTDAverage}\): Average of trips from (junction1 zone) to (junction2 zone).

### 3.2.5 Best routes assignment:

From the filtered edges, new routes can be drown as the best from the edges of BD>0. The propagation is governed by three guides:  
1. Starting from targets toward the higher RBWeight.  
2. The total length; a compromise depending on the network problem nature.

3. Include some edges of zero BD to attain connectivity between routes (if required).

### 3.3 Choice phase

Real world visualization may lead to some adjustments to the proposed routes. The AHPNDGIS is designed to export Shapefiles to KML format (which can be read by Google Earth software).

Sensitivity analysis can help also to find out the effect changing the adopted assumptions (especially in pairwising) by adopting other assumptions.

---

**Fig.2 Research stages**

#### 4 Baghdad Metro Case Study

##### 4.1 Raster data collection

A three bands raster map of Baghdad city created by National Imagery and Mapping Agency (NIMA) is used as a base map. Using ArcView, the distribution of urban area into segments and zones (each segment includes a group of zones) is traced on base map from hard copy of land use scenario which was done by JCCF [15] in 1990.
4.2 Tabular data collection

The forecasted socioeconomic data are taken from JCCF for the year 2015. Main socioeconomic data are population, employment, household size, and household number. Forecasted O/D person trips matrix between segments and intercity traffic volume are taken from JCCF study also.

Classified roads, intersections, public facilities, railroads, municipalities, commercial areas, and the polygon of the CBD are obtained from Baghdad mayoralty and Alsadeem [16].

The spatial indexing of the created Geodatabase facilitates the association of attributes with its related entities. Socioeconomic data and person trips matrix are related mainly to segments, therefore a formula to transform them to zones are adopted as in (3).

\[ \text{Zone Attribute} = \sum_{\text{Segment Attribute}} \left( \frac{\text{Zone Area} \times \text{Zone Population}}{\text{Zone Area} \times \text{Zone population}} \right) \]  

\[ \text{(3)} \]

The obtained data about features are drawn in different feature classes and gathered inside the geodatabase. The selected extent dimensions covered the urban area of the case study. The UTM coordination system is adopted.

4.3 Data adjustment

To attain compatibility between geodatabase components and the target of research, some necessary modifications on them are done. Data are oriented to focus on urban area. Zoning is rearranged accordingly.

The 73 zones according to JCCF became 80 after clipping orchards, water areas, and non urban lands. Zones homogeneity is targeted by the clipping and edges are allowed to intersect with the clipped area. The JCCF study marked a specific forecasted trend of urbanization based on CTS in 1980’s. No updated CTS were done to evaluate the proposed urbanization. Data from Baghdad mayoralty, Alsadeem, and Google Earth satellite images helped to make that evaluation. It shows some differences which supposed to be considered.

Removing zones of less urbanization and considering the existed or trend of last 20 years of urbanization led to re arrangement of study area to include 65 zones. The study area extent with these zones is shown in Fig. 3.

5 GIS-Based DSS Model Building

5.1 Geodatabase

The vector objects are drawn in 38 S UTM north zone and associated to related dataset components.

The main tabular data are population, employment, households, person trips, and vehicle trips.

The freeway and arterial roads intersections proposed as potential junctions (metro stations). Considering representative scatted distribution, filtration of 500 conformed intersections is carried out. It led to 225 potential junctions.

A buffer of 400m for each junction is created to assign five tabular attributes (criteria):
2. Employment (C2): no. of employments in buffer.
3. Intersections impact (C3): no. of other intersections in buffer.
4. Public facilities (C4): no. of public facilities multiplied by their attraction degree in buffer.
5. Commercial impact (C5): Commercial area in buffer divided by its commercial degree.

5.2 Metro routing model (MRM)

The potential junctions are ranked according to the five criteria using the AHPNDGIS software.

The pairwise matrix between criteria is assumed to be as in Table 1. The assumption is based on authors' knowledge, however it can be recommended by professional committee. The quantitative attributes are reflected into 9-scale AHP ranking using a designated method. The classification criteria based on reflecting (minimum to maximum) values into (1-9) scale.

Part of the list of junctions and consequently weights are shown in Appendix A. It shows also the eigenvector for each junction via each of the five attributes.

Junctions' center of gravity according to weight is found at (443120, 3688780). It is used as an origin to classify Junctions into three sectors based on weights and internal distances. Junctions laid in
intersection of CBD and each sector assumed as the potential main stations for that sector. The higher weight is the nominated target for the junctions which are located in the same sector. The three chosen targets according to this criterion are \(j88\), \(j102\), and \(j104\).

Table 1 Proposed junction’s criteria pairwise

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>7/6</td>
<td>7/4</td>
<td>7/5</td>
<td>7/6</td>
</tr>
<tr>
<td>C2</td>
<td>6/7</td>
<td>1</td>
<td>6/4</td>
<td>6/5</td>
<td>6/6</td>
</tr>
<tr>
<td>C3</td>
<td>4/7</td>
<td>4/6</td>
<td>1</td>
<td>4/5</td>
<td>4/6</td>
</tr>
<tr>
<td>C4</td>
<td>5/7</td>
<td>5/6</td>
<td>5/4</td>
<td>1</td>
<td>5/6</td>
</tr>
<tr>
<td>C5</td>
<td>6/7</td>
<td>6/6</td>
<td>6/4</td>
<td>6/5</td>
<td>1</td>
</tr>
</tbody>
</table>

To connect junctions by edges, the triangulated irregular network (TIN) is created; it produced 437 triangles and 661 edges which covered total Convex Hull for the junctions. The TIN is dedicated to simulate elevations and Digital Elevation Modeling (DEM). For the purpose of network model, the edges of the triangles are targeted. Therefore, some edges are neglected to focus on the study area. The final semi TIN model consisted of 420 non overlapped adjacent triangles and 644 edges as shown in Fig.4.

Fig 4 Semi TIN which include all potential junctions and edges in MRM

Like junctions, the 644 edges of MRM are subjected to AHP weighing steps. The assigned four attributes (criteria) to prioritize edges are:

1. Junction’s impact (C1): the average of the connected junctions’ weight.
2. To CBD person trips impact (C2): The summation of to CBD person trips per day of each zone (which the edge intersects with it) divided by the length of the intersection.
3. Commercial impact (C3): the percentage of the summation of different commercial parts of edge divided by the commercial degree of each part.
4. Geometry impact (C4): a scale from 1-9 which represents the easiness of constructing the line, it depends mainly on obstacles confliction.

The same implementation of AHP as described above is followed to prioritize the 644 edges, the same algorithm sequence to deal with the four attributes developed in AHPNDGIS.

The pairwise matrix of attributes assumed to be as in Table 2 which related to the AHP 9-scale ranking. The assumption is based on authors’ knowledge, however it can be recommended by professional committee. The edges' attributes are converted in runtime into 9-scale AHP ranking.

Table 2 Proposed edge’s criteria pairwise

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>4/9</td>
<td>4/5</td>
<td>4/6</td>
</tr>
<tr>
<td>C2</td>
<td>9/4</td>
<td>1</td>
<td>9/5</td>
<td>9/6</td>
</tr>
<tr>
<td>C3</td>
<td>5/4</td>
<td>5/9</td>
<td>1</td>
<td>5/6</td>
</tr>
<tr>
<td>C4</td>
<td>6/4</td>
<td>6/9</td>
<td>6/5</td>
<td>1</td>
</tr>
</tbody>
</table>

The label of each edge is the concatenation of attached junction’s labels as shown in Appendix B which depicts some weighing results of the edges.

6 Network Design

6.1 Routes propagation

The steps of routes propagation and tree branches simulation which explained in methodology are carried out. As expected, some routes fallen in circulation paths which are away from any target. The AHPNDGIS handled that, and completely embedded routes (in other routes) are neglected also.

A new line feature class is created to visualize edges which BD are more than zero. Using representative symbols, the edges of higher BD are drawn with higher line weight as shown in Fig 5.

The filtered routes of research case study include 238 edges (406 edges are neglected), acquire 41% of the total edges weight, and have a total length of 327 Km (the total edges length is 1048 Km). The method is designated to free the propagation of routes from the restriction of sinking in the same target of the first junction, therefore nine of the 77 routes sank in targets other than initial’s.

6.2 Rout branch weight (RBWeight)

The number of person trips per day of junction’s zones is added as a factor for this purpose as in equation (2). The RBWeight is added as new attribute of edges which visualized accordingly. The
schema is similar to Fig. 5. Edges have different thickness according to RBWeight instead of BD.

6.3 Best routes assignment

Based on the RB weight, a selection of best routes is started from the main junctions (proposed main stations). Movement toward the highest RB weight is adopted. The end of path can be dead end or a junction close to cordon road. The propagated paths are proposed as the metro routing network.

A compromise should arise to specify the total length of metro routing or the number of routes from each main station. Many concepts can be achieved to help in this decision. For the research case study, the values of RBWeight governed the number of route initiated from each main station. The total length is supposed to be less than 75 Km. The ranking approach assists in evaluating the length; routes can be added or deleted.

Applying the previous criteria, six routes are selected to cover the study area; four of them lay in east side of Tigris and two on the west of it. The list of each route is shown below:

1. E1: j84j88, j81j84, j177j178, j177j189, j189j191, j73j191, j70j73, j69j70.
2. E2: j98j104, j92j98, j92j93, j87j93, j44j87, j44j45, j45j46, j46j54, j54j60, j60j61.
5. W1: j95j102, j95j166, j166j168, j168j170, j169j170, j169j179, j179j180, j180j204.

To attain connection between those six routes, connections between main stations are invented by adding new edges to the previous lists:

C1: j94j95, j88j94, j88j90, j90j97, j97j98

C2: j101j104, j101j102

The underline edges in the previous lists have zero BD. They are added to attain more Route Branch weight for the whole route and to attain connectivity.

A brief description of the final metro routing network is shown in Table 3. There proposed schema and the cordon roads are shown in Fig. 6.

Table 3 Attributes of the metro routing network

<table>
<thead>
<tr>
<th>Route</th>
<th>Start to End</th>
<th>No. of edges</th>
<th>length (Km)</th>
<th>RBWeight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E1 j88-j69</td>
<td>9</td>
<td>9.0</td>
<td>1023</td>
</tr>
<tr>
<td>2</td>
<td>E2 j104-j61</td>
<td>10</td>
<td>10.9</td>
<td>368</td>
</tr>
<tr>
<td>3</td>
<td>E3 j104-j9</td>
<td>6</td>
<td>7.7</td>
<td>111</td>
</tr>
<tr>
<td>4</td>
<td>E4 j104-j12</td>
<td>4</td>
<td>5.3</td>
<td>287</td>
</tr>
<tr>
<td>5</td>
<td>W1 j102-j20</td>
<td>8</td>
<td>12.5</td>
<td>497</td>
</tr>
<tr>
<td>6</td>
<td>W2 j102-j137</td>
<td>8</td>
<td>12.2</td>
<td>538</td>
</tr>
<tr>
<td>7</td>
<td>C1 j95-j98</td>
<td>5</td>
<td>3.9</td>
<td>367</td>
</tr>
<tr>
<td>8</td>
<td>C2 j102-j104</td>
<td>2</td>
<td>2.1</td>
<td>10</td>
</tr>
<tr>
<td>∑</td>
<td></td>
<td>52 (from644)</td>
<td>63.6 Km</td>
<td>(From 1048 Km)</td>
</tr>
</tbody>
</table>

The length of the network found to be appropriate to offer conjunction of metro system with other transit modes.

6.4 XML format implementation

Converting the metro routing network from Shapefile to KML format found to be helpful in final touches of research. Google Earth software can be used to visualize the routes in real world which is based on satellite imaging of adequate resolution. Some spatial adjustments can be achieved accordingly.

The variation of resolution and preciseness between the adopted base map and image satellite
led to the need of adjusting some junctions. The adjustment of junctions based on eye altitude of about 150 meters. The shifting of some junctions from there coordinates to the adjusted locations led to some variation in routes lengths. The total length of all routes decreased to be 63.2 km instead of 63.6 Km. The routing network after adjustment is shown in Fig.7 in which labels referring to route name and station number.

Fig. 7 Adjusted metro network (KML format)

6.5 Sensitivity analysis

The evaluation of the found metro routing network is based on its contribution to achieve significant share of the whole transit volume in study area. The capacity of metro system is a function of headway, number and capacity of tracks, average velocity, and stations locations. In the scope of this research, stations locations are specified according to the applied socioeconomic data and some assumptions. The main assumptions are those to pairwise junctions and edges attributes. As mentioned before, they supposed to be built on specialized committee recommendations. However, there are other 59048 alternative cases of junction’s pairwising proposals to be tried, in addition to other 6560 cases of edge’s pairwising.

Three cases from different junctions attributes ranking and two cases from different edges attributes ranking are applied. The total cases are six as shown in Table 4. The variations in proposals of each case are submitted to find its effect on outputs of the next steps.

The number of distinct weights for junctions and edges has been affected slightly. The same effect noticed for the number of distinct filtered routes. Table 5 shows those effects and the distinct number of junctions and edges in filtered routes of each case.

Table 4 The proposed cases of sensitivity analysis

<table>
<thead>
<tr>
<th>Case</th>
<th>Junctions' Criteria</th>
<th>Edges' Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1</td>
<td>C2</td>
</tr>
<tr>
<td>Case 1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Case 2</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Case 3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Case 4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Case 5</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Case 6</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

The variation in ranking proposals of junctions and edges attributes shows some difference in filtered routes network.

Table 5 Comparison between results from each case

<table>
<thead>
<tr>
<th>Distinct Junctions weight</th>
<th>Distinct Edges weight</th>
<th>Distinct routes</th>
<th>No of junctions in routes</th>
<th>No of edges in routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>102</td>
<td>133</td>
<td>83</td>
<td>225</td>
</tr>
<tr>
<td>C2</td>
<td>102</td>
<td>143</td>
<td>82</td>
<td>225</td>
</tr>
<tr>
<td>C3</td>
<td>102</td>
<td>123</td>
<td>81</td>
<td>225</td>
</tr>
<tr>
<td>C4</td>
<td>102</td>
<td>133</td>
<td>81</td>
<td>225</td>
</tr>
<tr>
<td>C5</td>
<td>102</td>
<td>143</td>
<td>81</td>
<td>225</td>
</tr>
<tr>
<td>C6</td>
<td>102</td>
<td>123</td>
<td>82</td>
<td>225</td>
</tr>
</tbody>
</table>

7 Conclusions and Recommendations

7.1 Conclusions

1. The proposed metro network in [15] seems to match part of the presented network in this study. The same forecasted data and factors are used in both researches. Except the operational requirements of the metro, the clear contribution of criteria ranking (which based on designer assumption) draws unequal steps and outputs.

2. Network planning phases can be supported by the network analysis tools provided in GIS software. The research builds a logic approach to design networks using multi criteria ranking from potential network elements.

3. The variance of assumptions led to slightly deferred outputs. Committee assignment from experts to assign criteria ranking is crucial.

4. Network design problems other than transportation can be subjected to the same modeling approach.

5. The automation of main parts of research supports the efficiency of final output through the trial of different cases of inputs.
7.2 Recommendations
1. A study on modeling criteria in transportation network design can be done to evaluate adopted criteria via others. Different transportation zoning methods can be tested to find the best for each type of problems.
2. Expanding the automation to include all parts of modeling may produce robust software package for network design.
3. Updating the collected data to offer more number of criteria for junctions and edges will support the output quality and evaluate model implementation for up to 10 attributes.
4. The integration of metro network design with other transportation modal is a wider scope of transit system design. More detailed data about traffic distribution is required. The reiteration of design is the vital part in this case using more DSS tools.

Appendix

A Sample of the 225 normalized junctions

<table>
<thead>
<tr>
<th>Label</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>j1</td>
<td>0.0042</td>
<td>0.0025</td>
<td>0.0026</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.002873</td>
</tr>
<tr>
<td>j2</td>
<td>0.0062</td>
<td>0.0037</td>
<td>0.0026</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.003659</td>
</tr>
<tr>
<td>j3</td>
<td>0.0042</td>
<td>0.0037</td>
<td>0.0026</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.003139</td>
</tr>
<tr>
<td>j4</td>
<td>0.0042</td>
<td>0.0037</td>
<td>0.0026</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.003139</td>
</tr>
<tr>
<td>j5</td>
<td>0.0021</td>
<td>0.0037</td>
<td>0.0077</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.003351</td>
</tr>
<tr>
<td>j6</td>
<td>0.0031</td>
<td>0.0062</td>
<td>0.0154</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.005243</td>
</tr>
<tr>
<td>j7</td>
<td>0.0031</td>
<td>0.0075</td>
<td>0.0077</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.004410</td>
</tr>
<tr>
<td>j8</td>
<td>0.0031</td>
<td>0.0037</td>
<td>0.0026</td>
<td>0.0027</td>
<td>0.0021</td>
<td>0.002879</td>
</tr>
<tr>
<td>j9</td>
<td>0.0073</td>
<td>0.0037</td>
<td>0.0026</td>
<td>0.0080</td>
<td>0.0021</td>
<td>0.004867</td>
</tr>
<tr>
<td>j10</td>
<td>0.0042</td>
<td>0.0062</td>
<td>0.0026</td>
<td>0.0053</td>
<td>0.0021</td>
<td>0.004145</td>
</tr>
</tbody>
</table>

B Sample of the 644 normalized edges

<table>
<thead>
<tr>
<th>Label</th>
<th>weight</th>
<th>Label</th>
<th>weight</th>
<th>Label</th>
<th>weight</th>
<th>Label</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>j30j32</td>
<td>0.00115</td>
<td>j14j21</td>
<td>0.00128</td>
<td>j81j84</td>
<td>0.00140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j32j33</td>
<td>0.00115</td>
<td>j13j14</td>
<td>0.00128</td>
<td>j82j84</td>
<td>0.00140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j32j41</td>
<td>0.00115</td>
<td>j13j13</td>
<td>0.00128</td>
<td>j82j83</td>
<td>0.00070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j32j40</td>
<td>0.00128</td>
<td>j13j13</td>
<td>0.00118</td>
<td>j83j84</td>
<td>0.00243</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j34j40</td>
<td>0.00115</td>
<td>j13j13</td>
<td>0.00121</td>
<td>j84j88</td>
<td>0.00301</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j34j43</td>
<td>0.00128</td>
<td>j13j13</td>
<td>0.00128</td>
<td>j88j89</td>
<td>0.00508</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j32j34</td>
<td>0.00115</td>
<td>j13j13</td>
<td>0.00108</td>
<td>j83j89</td>
<td>0.00331</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j30j34</td>
<td>0.00115</td>
<td>j13j13</td>
<td>0.00121</td>
<td>j83j88</td>
<td>0.00331</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j34j39</td>
<td>0.00115</td>
<td>j13j13</td>
<td>0.00121</td>
<td>j88j91</td>
<td>0.00313</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j38j39</td>
<td>0.00115</td>
<td>j12j12</td>
<td>0.00086</td>
<td>j90j91</td>
<td>0.00301</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

References:
