Grocery Store Design

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Abstract

Donald Knuth, a well-known person in computer science, used graph theory to design his kitchen. While utilizing graph theory for his personal challenge, he discovered that the garbage can is a highly desirable neighbor node; apparently everything led back to and wanted to be next to the trashcan!

Fortunately in our application of graph theory in creating a newly designed floor plan for you, we did not have this challenge. Everything in our recommended floor plan leads to both increased revenues, for you, our client, and to smiles on your valued customers faces. However, we did follow in his footsteps in a similar way. We applied modern graph theory to design a more efficient grocery store. To design this grocery store, two different applications of graph theory were used to find a shortest path for "must-have" grocery items: Floyd's algorithm, and a Heuristic algorithm. These "must-have" items have nearly 100% penetration in both your existing store and our recommended store. Both premium priced items and impulse buying items were placed along the calculated shortest path in our well-organized store. After comparing and contrasting our suggested store to your existing store, we are confident that our store is a superior design and is highly worthy of your consideration!

1 The Challenge

Our challenge is as follows: to meet the requirements of the February 1, 2005, RFP of Gleason's Grocers to create a grocery store floor plan to increase profit while meeting the needs of customers. Our research shows each week consumers spend an average of 1.5 hours grocery shopping during 2.5 trips to the grocery store. Eighty-five percent (85%) of their purchases are to replenish staple items. Consumers have identified quick and efficient shopping as one of the most desired traits in their evaluation of grocery stores. Degree of loyalty is affected by shoppers' evaluation of stores and we wish to design a floor plan to appeal to both Large Basket Shoppers (LBS) and Frequent Shoppers (FS).

1.1 The Reasoning

Eighty-one percent (81%) of shoppers come into a grocery store with either a physical or mental shopping list. Let's assume that every shopper wishes to find and purchase those items in as little time as possible. In effect, taking the "shortest path" from the store entrance to the desired items and back to the entrance. In our research, we identified milk, meat, paper products, frozen foods, and breads/cereals as the most popular "must-have" items on a customers list. Additionally, most shoppers will buy items not included on their list. For all intent and purposes, we will call these items impulse buys. Thinking logically, one may perhaps conclude that the more items that a customer passes while shopping for "must-haves", the more impulse buys a customer will make. However, the Law of Diminishing Returns comes into play here. Forcing exhausted customers past all items in a store is a negative experience which would prevent return visits. Store design must strike a balance to invite return visits while maximizing the opportunities for impulse buys. Considering this reasoning, our recommended floor plan has as many items as possible along the shortest path. One may think that placing "must-haves" in close proximity to one another would be optimal. There are several problems with this theory. One problem is: if the "must-have" items are in close proximity to one another, there will be little to no impulse buying. Although this may be acceptable to the customer, it would have minimal benefit to you, the store owner. Another problem is: some "must-have" items need to be placed in designated areas. For example, it is preferable that milk and meats are placed in the rear or on the side of stores in refrigeration units due to the electricity costs for running the units and accessibility for stocking. Our research also shows a consumer trend to "category" rather than "product" purchasing. This means a shopper's list will tend to think more of a meal rather than the individual components of the meal. Grouping products by category, as our floor plan does, allows flexibility to meet the needs of both category and product shoppers.

1.2 The Set-Up

Using graph theory, along with the considerations mentioned above, we designed what we believe to be a new and improved grocery store floor plan. After careful consideration, we determined that the vertices of this plan would include the end of the shelves and the middle of an aisle. If a customer is at the end of a shelf and another shelf is next to the customer (across the aisle), this scenario represents the same vertex. The edges include any aisle that takes a customer from one vertex to the next. After defining a vertex and an edge, graph theory was utilized to calculate and determine a shortest path to our "must-have" items.

2 Shortest Path Calculation Methodology

To calculate the shortest path from the entrance to our five items and back to the entrance, we employed a two-step strategy. The first step applied Floyd's Algorithm to determine the shortest path between all pairs of vertices. After calculating this shortest path, a heuristic algorithm involving the six vertices (entrance plus five) was utilized calculating the shortest circuit.

2.1 Floyds Algorithm

We created an adjacency matrix representing the distance in feet between each of the connected vertices and labeled this matrix as $M(0)$. If vertex i was not connected to vertex j, then we entered ∞ for $M(0)_{i,j}$.

To calculate $M(1)_{i,j}$, we determined the shortest path from vertex i to vertex j allowing the vertex 1 to be used as an intermediate step if necessary. Then, for $M(2)_{i,j}$, we determined the shortest path from vertex i to vertex j allowing vertex 1 or vertex 2 or both to be used as intermediate steps. In general, $M(x)_{i,j}$ represented the shortest path from vertex i to vertex j allowing any vertex or combination of vertices from 1 to x to be used as intermediate steps. If our graph had n vertices, then the entries of $M(n)$ would represent the shortest distance for each pair of vertices using any vertex (or vertices) as intermediate steps. Each calculation was performed as follows:

$$M(x)_{i,j} = min[(M(x-1)_{i,j}), (M(x-1)_{i,x} + M(x-1)_{x,j})].$$

We completed this calculation n^3 times to find $M(n)$ [1].

The algorithm describing this process is shown below [8] .

$n \leftarrow rows[W]$
$D^{(0)} \leftarrow W$
for $k \leftarrow 1$ **to** n
    do for $i \leftarrow 1$ **to** n
        do for $j \leftarrow 1$ **to** n
            do $d_{ij}^{(k)} \leftarrow min(d_{ij}^{(k-1)}, d_{ik}^{(k-1)} + d_{kj}^{(k-1)})$
return $D^{(n)}$

For $W = (w_{ij})$, where

$$W_{ij} = \begin{cases} 0 & \text{if } i = j, \\ \text{the weight of the directed edge } (i,j) & \text{if } i \neq j \text{ and } (i,j) \in E, \\ \infty & \text{if } i \neq j \text{ and } (i,j) \notin E. \end{cases}$$

2.2 Heuristic Algorithm

Now that we know the shortest distance between any pair of vertices, we created a new adjacency matrix which only includes six vertices (the entrance and our five must-have items). To calculate the shortest circuit through the store beginning at the entrance, we applied a heuristic algorithm. In this algorithm, we simply selected the shortest path to an unvisited vertex in the matrix. It is not possible to prove that this is the shortest circuit, but we believe it is reasonable to expect that a shopper would select a circuit in the same manner.

3 Current Floor Plan

For the existing store, we used a model of a Kroger store that is located in Eastern Kentucky. We chose this store due to its commonality in layout and placement of stock.

The "must-have" items and the entrance are positioned as follows:

- Entrance - Vertex 1
- Meat - Vertex 15
- Milk - Vertex 20
- Paper Products - Vertex 23
- Breads/Cereals - Vertex 45
- Frozen Foods - Vertex 49

Having applied the above mentioned algorithms to this floor plan, we found the following adjacency matrix. This matrix shows us the distance in feet from any of our "must-have" items or the entrance to any other of these vertices.

Adjacency Matrix for Heuristic Algorithm
Our Current Floor Plan

	1	**15**	**20**	**23**	**45**	**49**
1	0	162	263	209	105	174
15	162	0	115	247	66	112
20	263	115	0	132	158	112
23	209	247	132	0	213	117
45	105	66	158	213	0	178
49	174	112	112	117	178	0

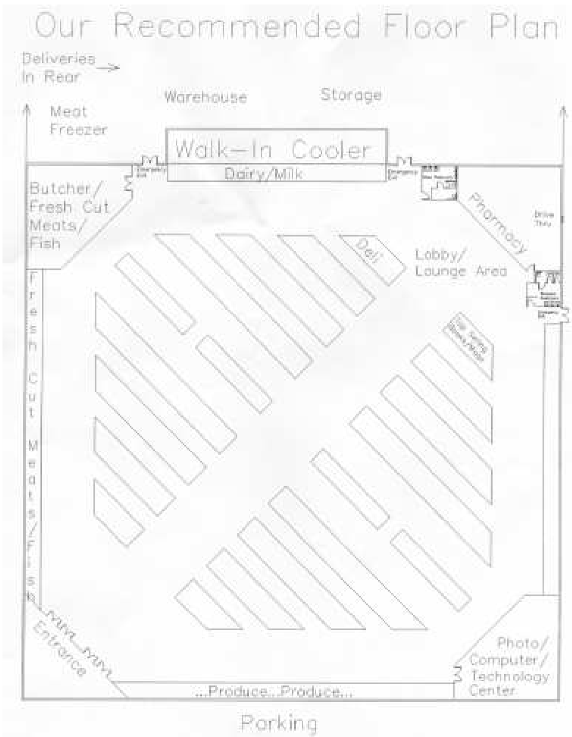
Using the above methods, the shortest path beginning and returning to the entrance (Vertex 1) passing through our five important items is:

$1 \rightarrow 44 \rightarrow 45 \rightarrow 15 \rightarrow 16 \rightarrow 17 \rightarrow 49 \rightarrow 18 \rightarrow 19 \rightarrow 20 \rightarrow 21 \rightarrow 22 \rightarrow 23 \rightarrow 59 \rightarrow 58 \rightarrow 52 \rightarrow 50 \rightarrow 48 \rightarrow 46 \rightarrow 44 \rightarrow 1$

This path would require a customer to walk 736 feet with 14 intermediate vertices.

4 Our Recommended Floor Plan

In the new store, we placed our "must-haves" in locations around the store that would be cost-efficient and convenient for the owners and employees of the store.



We positioned the "must-have" items and entrance as follows:

- Entrance - Vertex 1
- Milk - Vertex 15

- Meat - Vertex 18
- Paper Products - Vertex 32
- Frozen Foods - Vertex 38
- Breads/Cereals - Vertex 40

This positioning of the items in relation to the other items and the entrance produced this adjacency matrix for our recommended floor plan.

Adjacency Matrix for Heuristic Algorithm
Our Recommended Floor Plan

	1	**15**	**18**	**32**	**38**	**40**
1	0	245	174	143	174	174
15	245	0	84	169	112	155
18	174	84	0	85	60	188
32	143	169	85	0	113	122
38	174	112	60	113	0	135
40	174	155	188	122	135	0

Using the above methods, the shortest path beginning and returning to the entrance (Vertex 1) passing through our five important items is:

$1 \to 25 \to 28 \to 31 \to 32 \to 19 \to 18 \to 37 \to 38 \to 41 \to 17 \to 16 \to 15 \to 50 \to 49 \to 46 \to 43 \to 40 \to 36 \to 34 \to 31 \to 28 \to 25 \to 1$

This path would require a customer to walk 728 feet with 17 intermediate vertices.

5 Summary

So what does all of this information mean to you?
Our design saves you money NOW!

- Existing store design 277 feet by 210 feet = 58,170 square feet
- Proposed store design 240 feet by 240 feet = 57,600 square feet

At the current construction cost of $250 per square foot, this difference of 570 square feet translates to an instant savings of $142,500 per store!
Our design increases your revenue potential!
A ”list” shopper (81% of your clients), , following the shortest path to the must-have items, passes 14 opportunities for impulse buying in your existing store. In our proposed design, the same customer passes 17 opportunities for impulse buying. This represents a more than 20% increase in revenue potential!
Our design keeps your customers happy!
A ”no-list” shopper (19% of your clients) may browse the category-style floor-plan, providing the ”enriching” experience our research shows consumers are increasingly demanding. Additionally, there is sufficient aisle space for strategically placed wings and shoppers or off-shelf displays (convenient for both category shopping and increased revenue.)

6 The Solution

Our design is practical.

- Save money on construction while increasing revenue potential. Our mathematical design is innovative and forward thinking.
- The computerized model presented by Green Apple Consulting, Incorporated is one step away from PDA usage on every shopping cart. Gleason's Grocers will lead the country in innovation, design and customer satisfaction.
- PDA usage is one-step away from the potential of RFID technology to track Inventory and provide quicker check-out lines for Enterprise Resource Planning (ERP).
- As our partnership progresses to its next stages, our advanced mathematical thinking will help us re-define category decision trees and cross category purchasing dynamics. Our design is consumer-oriented.
- Category shopping is on the rise (from 10 to 20% in the last year) and our flexible floor plan accommodates this consumer trend.
- Consumers are increasingly looking to shopping for food to be an enriching experience and our flexible floor plan easily leads to the next step of "food-centric" islands in the store.
- The straight-forward, dynamic floor plan easily accommodates the new shoppers of tomorrow - men and children of single parents.

Green Apple Consulting, Incorporated- "Creating global systems while accommodating local differences."

References

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[5] Path problems in directed graphs. http://www.csse.monash.edu.au/ lloyd/tildeAlgDS/Graph/Directed/.

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[8] Thomas H. Cormen et al. *Introduction to Algorithms*, chapter 25. Prentice-Hall, second edition, 2001.

[9] Mr. Gene King, Super Kroger Manager, Winchester, KY. Personal Interviews, February 2005.

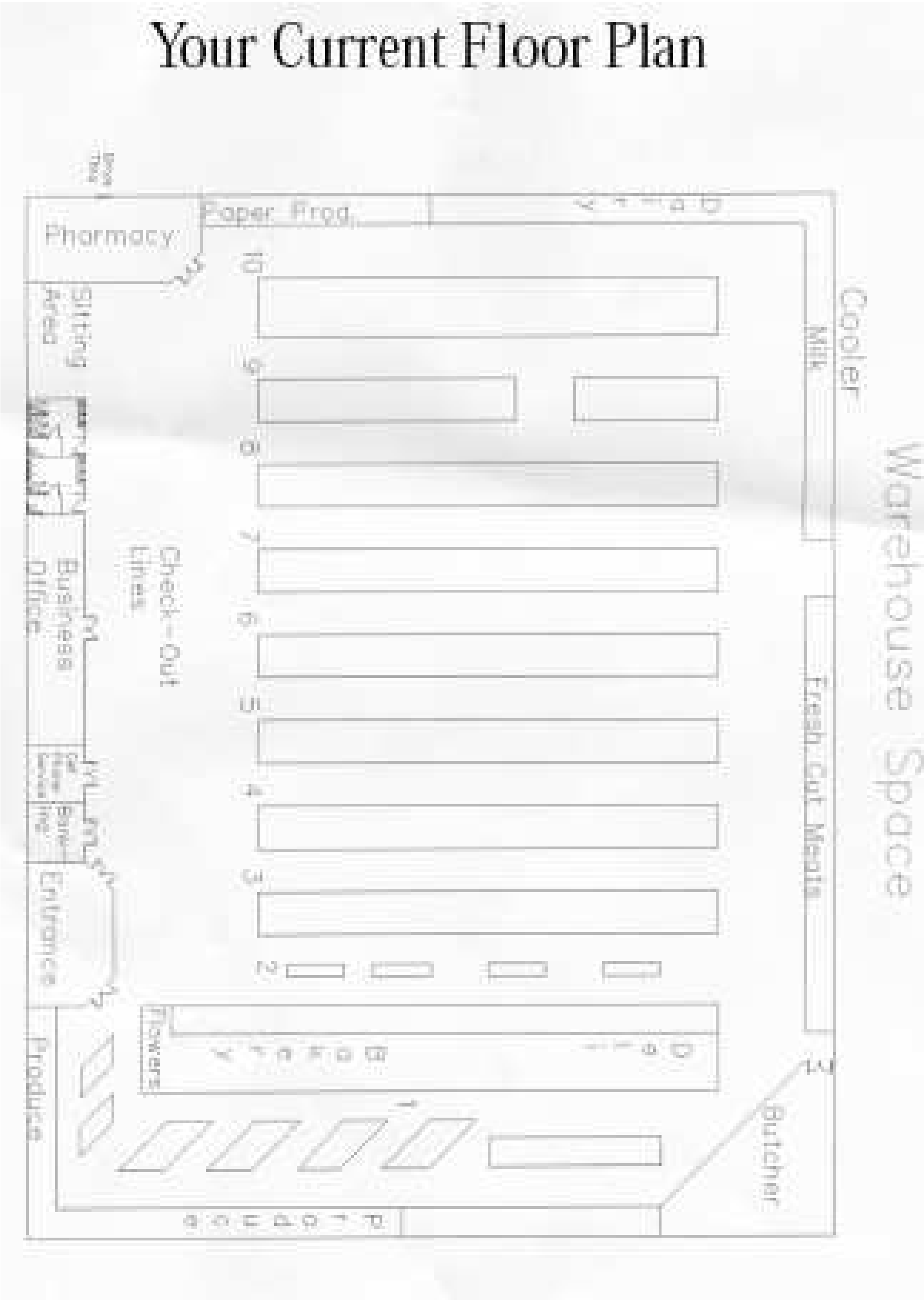
[10] Mr. Michael Eddy, Assistant Manager, The Kroger Co., Clarksburg, West Virginia. Personal Interviews, March 2005.

[11] Richard Neapolitan et al. *Foundations of Algorithms*, chapter 3. Jones and Bartlett Publishers, 1997.

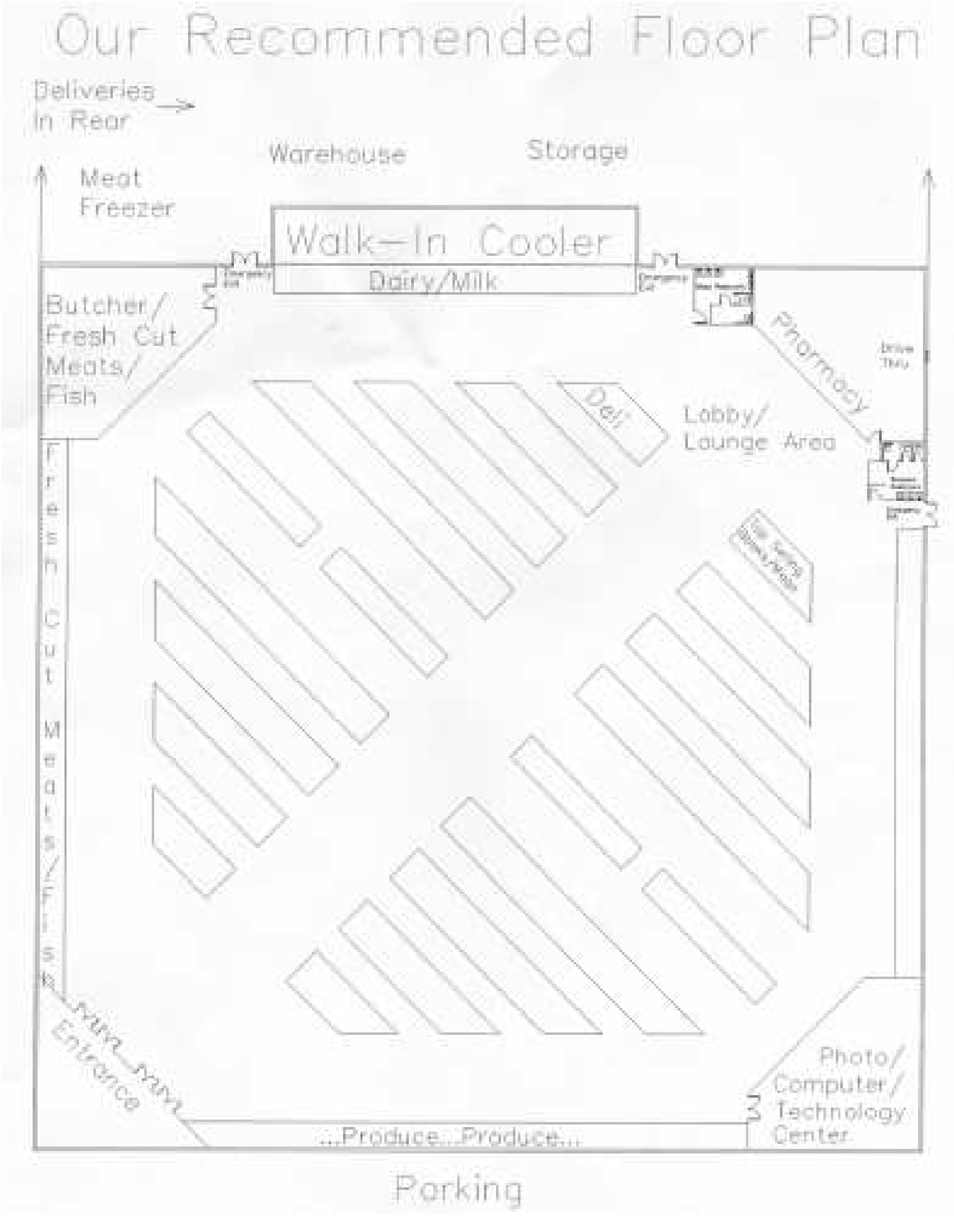
Appendix

The appendix contains full-size CAD drawings of both floor plans and matrices used when making calculations with Floyd's Algorithm.

A full-size CAD drawing of the current floor plan.



A full-size CAD drawing of the recommended floor plan.



An adjacency matrix of the current floor plan made by calculations of Floyd's Algorithm.

Existing Floorplan
Adjancency Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	39		32																									30	30
2	39	0	19	15																										
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31	0	15	15																										
32	15	0		13	23																								
33	15		0	13		23																							
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54																							68	0	32				
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56																									32	0	68		
57																									41	68	0	41	41
58																						23	41				41	0	23
59																											41	23	0

A shortest-path matrix of the current floor plan made by calculations of Floyd's Algorithm.

Existing Floorplan
Shortest Path - All Verticies

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0	39	58	32	58	71	94	117	158	158	199	171	150	162	162	171	194	217	240	263	271	280	209	174	138	125	87	49	30	30
2	39	0	19	15	38	54	77	100	141	141	182	186	165	186	201	210	233	256	279	302	310	319	248	213	177	164	126	88	69	69
3	58	19	0	34	19	42	65	88	129	129	170	200	184	205	220	229	252	275	298	321	329	338	267	232	196	183	145	107	88	88
4	32	15	34	0	26	39	62	85	126	126	167	171	150	171	188	203	226	249	272	295	303	312	241	206	170	157	119	81	62	56
5	58	38	19	26	0	23	46	69	110	110	151	181	176	197	214	229	252	275	298	321	329	338	267	232	196	183	145	107	88	82
6	71	54	42	39	23	0	23	46	87	87	128	158	179	184	207	230	253	276	299	322	342	351	280	245	209	196	158	120	101	95
7	94	77	65	62	46	23	0	23	64	64	105	135	156	161	184	207	230	253	276	299	322	360	303	268	232	219	181	143	124	118
8	117	100	88	85	69	46	23	0	41	41	82	112	133	138	161	184	207	230	253	276	299	337	326	291	255	242	204	166	147	141
9	158	141	129	126	110	87	64	41	0	82	41	71	92	97	120	143	166	189	212	235	258	296	367	332	296	283	245	207	188	182
10	158	141	129	126	110	87	64	41	82	0	41	71	92	97	120	143	166	189	212	235	258	296	367	332	296	283	245	207	188	182
11	199	182	170	167	151	128	105	82	41	41	0	30	51	56	79	102	125	148	171	194	217	255	326	347	315	302	267	229	222	179
12	171	186	200	171	181	158	135	112	71	71	30	0	21	26	49	72	95	118	141	164	187	225	296	317	285	272	237	199	192	149
13	150	165	184	150	176	179	156	133	92	92	51	21	0	21	44	67	90	113	136	159	182	220	291	312	278	265	228	190	171	128
14	162	186	205	171	197	184	161	138	97	97	56	26	21	0	23	46	69	92	115	138	161	199	270	291	259	246	211	173	168	132
15	162	201	220	188	214	207	184	161	120	120	79	49	44	23	0	23	46	69	92	115	138	176	247	268	236	223	188	168	168	132
16	171	210	229	203	229	230	207	184	143	143	102	72	67	46	23	0	23	46	69	92	115	153	224	245	213	200	170	168	168	155
17	194	233	252	226	252	253	230	207	166	166	125	95	90	69	46	23	0	23	46	69	92	130	201	222	190	177	170	168	173	178
18	217	256	275	249	275	276	253	230	189	189	148	118	113	92	69	46	23	0	23	46	69	107	178	199	171	168	170	177	196	201
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21	271	310	329	303	329	342	322	299	258	258	217	187	182	161	138	115	92	69	46	23	0	38	109	171	171	174	196	231	250	255
22	280	319	338	312	338	351	360	337	296	296	255	225	220	199	176	153	130	107	84	61	38	0	71	133	150	163	201	239	258	264
23	209	248	267	241	267	280	303	326	367	367	326	296	291	270	247	224	201	178	155	132	109	71	0	62	79	92	130	168	187	193
24	174	213	232	206	232	245	268	291	332	332	347	317	312	291	268	245	222	199	176	171	171	133	62	0	36	49	87	125	144	185
25	138	177	196	170	196	209	232	255	296	296	315	285	278	259	236	213	190	171	171	171	171	150	79	36	0	13	51	89	108	150
26	125	164	183	157	183	196	219	242	283	283	302	272	265	246	223	200	177	168	168	171	174	163	92	49	13	0	38	76	95	137
27	87	126	145	119	145	158	181	204	245	245	267	237	228	211	188	170	170	170	170	191	196	201	130	87	51	38	0	38	57	100
28	49	88	107	81	107	120	143	166	207	207	229	199	190	173	168	168	168	177	200	223	231	239	168	125	89	76	38	0	19	62
29	30	69	88	62	88	101	124	147	188	188	222	192	171	168	168	168	173	196	219	242	250	258	187	144	108	95	57	19	0	43
30	30	69	88	56	82	95	118	141	182	182	179	149	128	132	132	155	178	201	224	247	255	264	193	185	150	137	100	62	43	0
31	39	54	73	39	65	78	101	124	165	165	162	132	111	132	149	172	195	218	241	264	272	281	210	202	167	154	117	79	60	17
32	54	69	88	54	80	93	116	139	180	180	147	117	96	117	140	163	186	209	232	255	278	296	225	217	182	169	132	94	75	32
33	54	69	88	54	80	93	116	139	180	180	147	117	96	117	140	163	186	209	232	255	278	296	225	217	182	169	132	94	75	32
34	67	82	101	67	93	106	129	152	178	178	137	107	86	107	130	153	176	199	222	245	268	306	238	230	195	182	145	107	88	45
35	77	92	111	77	103	116	139	162	165	165	124	94	73	94	117	140	163	186	209	232	255	293	248	240	205	192	155	117	98	55
36	77	92	111	77	103	116	139	162	165	165	124	94	73	94	117	140	163	186	209	232	255	293	248	240	205	192	155	117	98	55
37	92	107	126	92	118	131	154	177	150	150	109	79	58	79	102	125	148	171	194	217	240	278	263	255	220	207	170	132	113	70
38	107	122	141	107	133	146	169	176	135	135	94	64	43	64	87	110	133	156	179	202	225	263	278	270	235	222	185	147	128	85
39	107	122	141	107	133	146	169	176	135	135	94	64	43	64	87	110	133	156	179	202	225	263	278	270	235	222	185	147	128	85
40	122	137	156	122	148	161	184	161	120	120	79	49	28	49	72	95	118	141	164	187	210	248	293	285	250	237	200	162	143	100
41	137	152	171	137	163	176	169	146	105	105	64	34	13	34	57	80	103	126	149	172	195	233	304	300	265	252	215	177	158	115
42	137	152	171	137	163	176	169	146	105	105	64	34	13	34	57	80	103	126	149	172	195	233	304	300	265	252	215	177	158	115
43	96	135	154	122	148	161	184	204	163	163	122	92	87	66	66	89	112	135	158	181	204	242	236	228	193	180	145	107	102	66
44	39	78	97	71	97	110	133	156	197	197	188	158	151	132	132	132	155	178	201	224	232	241	170	162	127	114	79	41	36	23
45	105	144	163	137	163	176	199	222	186	186	145	115	110	89	66	66	89	112	135	158	181	219	213	205	170	157	122	102	102	89
46	62	101	120	94	120	133	156	179	220	220	211	181	174	155	132	132	132	155	178	201	209	218	147	139	104	91	56	36	41	46
47	128	167	186	160	186	199	222	245	209	209	168	138	133	112	89	66	66	89	112	135	158	196	190	182	147	134	104	102	107	112
48	85	124	143	117	143	156	179	202	243	243	234	204	197	178	155	132	132	132	155	178	186	195	124	116	81	68	38	45	64	69
49	151	190	209	183	209	222	245	268	232	232	191	161	156	135	112	89	66	66	89	112	135	173	167	159	124	111	104	111	130	135
50	108	147	166	140	166	179	202	225	266	266	257	227	220	201	178	155	132	132	132	155	163	172	101	93	58	45	38	68	87	92
51	174	213	232	206	232	245	268	291	255	255	214	184	179	158	135	112	89	66	66	89	112	150	144	136	105	102	104	134	153	158
52	131	170	189	163	189	202	225	248	289	289	280	250	243	224	201	178	155	132	132	135	140	149	78	70	39	36	56	91	110	115
53	172	211	230	204	230	243	266	289	306	306	265	235	230	209	186	163	140	117	94	94	99	137	96	88	77	77	97	132	151	156
54	240	279	298	272	298	311	302	279	238	238	197	167	162	141	118	95	72	49	26	26	49	87	146	150	145	145	165	200	219	224
55	213	252	271	245	271	284	307	311	270	270	229	199	194	173	150	127	104	81	58	58	58	96	114	118	118	118	138	173	192	197
56	245	284	303	277	303	316	325	302	261	261	220	190	185	164	141	118	95	72	49	26	26	64	135	145	145	148	170	205	224	229
57	195	234	253	227	253	266	289	312	311	311	270	240	235	214	191	168	145	122	99	94	94	132	73	77	77	80	118	155	174	179
58	154	193	212	186	212	225	248	271	312	312	303	273	266	247	224	201	178	155	135	135	135	126	55	47	36	39	77	114	133	138
59	177	216	235	209	235	248	271	294	335	335	311	281	276	255	232	209	186	163	140	135	135	103	32	36	47	60	98	136	155	161

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
1	39	54	54	67	77	77	92	107	107	122	137	137	96	39	105	62	128	85	151	108	174	131	172	240	213	245	195	154	177
2	54	69	69	82	92	92	107	122	122	137	152	152	135	78	144	101	167	124	190	147	213	170	211	279	252	284	234	193	216
3	73	88	88	101	111	111	126	141	141	156	171	171	154	97	163	120	186	143	209	166	232	189	230	298	271	303	253	212	235
4	39	54	54	67	77	77	92	107	107	122	137	137	122	71	137	94	160	117	183	140	206	163	204	272	245	277	227	186	209
5	65	80	80	93	103	103	118	133	133	148	163	163	148	97	163	120	186	143	209	166	232	189	230	298	271	303	253	212	235
6	78	93	93	106	116	116	131	146	146	161	176	176	161	110	176	133	199	156	222	179	245	202	243	311	284	316	266	225	248
7	101	116	116	129	139	139	154	169	169	184	169	169	184	133	199	156	222	179	245	202	268	225	266	302	307	325	289	248	271
8	124	139	139	152	162	162	177	176	176	161	146	146	204	156	222	179	245	202	268	225	291	248	289	279	311	302	312	271	294
9	165	180	180	178	165	165	150	135	135	120	105	105	163	197	186	220	209	243	232	266	255	289	306	238	270	261	311	312	335
10	165	180	180	178	165	165	150	135	135	120	105	105	163	197	186	220	209	243	232	266	255	289	306	238	270	261	311	312	335
11	162	147	147	137	124	124	109	94	94	79	64	64	122	188	145	211	168	234	191	257	214	280	265	197	229	220	270	303	311
12	132	117	117	107	94	94	79	64	64	49	34	34	92	158	115	181	138	204	161	227	184	250	235	167	199	190	240	273	281
13	111	96	96	86	73	73	58	43	43	28	13	13	87	151	110	174	133	197	156	220	179	243	230	162	194	185	235	266	276
14	132	117	117	107	94	94	79	64	64	49	34	34	66	132	89	155	112	178	135	201	158	224	209	141	173	164	214	247	255
15	149	140	140	130	117	117	102	87	87	72	57	57	66	132	66	132	89	155	112	178	135	201	186	118	150	141	191	224	232
16	172	163	163	153	140	140	125	110	110	95	80	80	89	132	66	132	66	132	89	155	112	178	163	95	127	118	168	201	209
17	195	186	186	176	163	163	148	133	133	118	103	103	112	155	89	132	66	132	66	132	89	155	140	72	104	95	145	178	186
18	218	209	209	199	186	186	171	156	156	141	126	126	135	178	112	155	89	132	66	132	66	132	117	49	81	72	122	155	163
19	241	232	232	222	209	209	194	179	179	164	149	149	158	201	135	178	112	155	89	132	66	132	94	26	58	49	99	135	140
20	264	255	255	245	232	232	217	202	202	187	172	172	181	224	158	201	135	178	112	155	89	135	94	26	58	26	94	135	135
21	272	278	278	268	255	255	240	225	225	210	195	195	204	232	181	209	158	186	135	163	112	140	99	49	58	26	94	135	135
22	281	296	296	306	293	293	278	263	263	248	233	233	242	241	219	218	196	195	173	172	150	149	137	87	96	64	132	126	103
23	210	225	225	238	248	248	263	278	278	293	304	304	236	170	213	147	190	124	167	101	144	78	96	146	114	135	73	55	32
24	202	217	217	230	240	240	255	270	270	285	300	300	228	162	205	139	182	116	159	93	136	70	88	150	118	145	77	47	36
25	167	182	182	195	205	205	220	235	235	250	265	265	193	127	170	104	147	81	124	58	105	39	77	145	118	145	77	36	47
26	154	169	169	182	192	192	207	222	222	237	252	252	180	114	157	91	134	68	111	45	102	36	77	145	118	148	80	39	60
27	117	132	132	145	155	155	170	185	185	200	215	215	145	79	122	56	104	38	104	38	104	56	97	165	138	170	118	77	98
28	79	94	94	107	117	117	132	147	147	162	177	177	107	41	102	36	102	45	111	68	134	91	132	200	173	205	155	114	136
29	60	75	75	88	98	98	113	128	128	143	158	158	102	36	102	41	107	64	130	87	153	110	151	219	192	224	174	133	155
30	17	32	32	45	55	55	70	85	85	100	115	115	66	23	89	46	112	69	135	92	158	115	156	224	197	229	179	138	161
31	0	15	15	28	38	38	53	68	68	83	98	98	83	40	106	63	129	86	152	109	175	132	173	241	214	246	196	155	178
32	15	0	26	13	23	26	38	53	53	68	83	83	98	55	121	78	144	101	167	124	190	147	188	256	229	261	211	170	193
33	15	26	0	13	26	23	38	53	53	68	83	83	98	55	121	78	144	101	167	124	190	147	188	256	229	261	211	170	193
34	28	13	13	0	13	13	28	43	43	58	73	73	111	68	134	91	157	114	180	137	203	160	201	248	242	271	224	183	206
35	38	23	26	13	0	26	15	30	30	45	60	60	121	78	144	101	167	124	190	147	213	170	211	235	252	258	234	193	216
36	38	26	23	13	26	0	15	30	30	45	60	60	121	78	144	101	167	124	190	147	213	170	211	235	252	258	234	193	216
37	53	38	38	28	15	15	0	15	15	30	45	45	136	93	159	116	182	139	205	162	228	185	226	220	252	243	249	208	231
38	68	53	53	43	30	30	15	0	30	15	30	30	130	108	153	131	176	154	199	177	222	200	241	205	237	228	264	223	246
39	68	53	53	43	30	30	15	30	0	15	30	30	130	108	153	131	176	154	199	177	222	200	241	205	237	228	264	223	246
40	83	68	68	58	45	45	30	15	15	0	15	15	115	123	138	146	161	169	184	192	207	215	256	190	222	213	263	238	261
41	98	83	83	73	60	60	45	30	30	15	0	26	100	138	123	161	146	184	169	207	192	230	243	175	207	198	248	253	276
42	98	83	83	73	60	60	45	30	30	15	26	0	100	138	123	161	146	184	169	207	192	230	243	175	207	198	248	253	276
43	83	98	98	111	121	121	136	130	130	115	100	100	0	66	132	89	155	112	178	135	201	158	199	184	216	207	222	181	204
44	40	55	55	68	78	78	93	108	108	123	138	138	66	0	66	23	89	46	112	69	135	92	133	201	174	206	156	115	138
45	106	121	121	134	144	144	159	153	153	138	123	123	132	66	0	66	132	89	155	112	178	135	176	161	193	184	199	158	181
46	63	78	78	91	101	101	116	131	131	146	161	161	89	23	66	0	66	23	89	46	112	69	110	178	151	183	133	92	115
47	129	144	144	157	167	167	182	176	176	161	146	146	155	89	132	66	0	66	132	89	155	112	153	138	170	161	176	135	158
48	86	101	101	114	124	124	139	154	154	169	184	184	112	46	89	23	66	0	66	23	89	46	87	155	128	160	110	69	92
49	152	167	167	180	190	190	205	199	199	184	169	169	178	112	155	89	132	66	0	66	132	89	130	115	147	138	153	112	135
50	109	124	124	137	147	147	162	177	177	192	207	207	135	69	112	46	89	23	66	0	66	23	64	132	105	137	87	46	69
51	175	190	190	203	213	213	228	222	222	207	192	192	201	135	178	112	155	89	132	66	0	66	107	92	124	115	130	89	112
52	132	147	147	160	170	170	185	200	200	215	230	230	158	92	135	69	112	46	89	23	66	0	41	109	82	114	64	23	46
53	173	188	188	201	211	211	226	241	241	256	243	243	199	133	176	110	153	87	130	64	107	41	0	68	41	73	82	41	64
54	241	256	256	248	235	235	220	205	205	190	175	175	184	201	161	178	138	155	115	132	92	109	68	0	32	52	73	109	114
55	214	229	229	242	252	252	252	237	237	222	207	207	216	174	193	151	170	128	147	105	124	82	41	32	0	32	41	82	82
56	246	261	261	271	258	258	243	228	228	213	198	198	207	206	184	183	161	160	138	137	115	114	73	52	32	0	68	109	109
57	196	211	211	224	234	234	249	264	264	263	248	248	222	156	199	133	176	110	153	87	130	64	82	73	41	68	0	41	41
58	155	170	170	183	193	193	208	223	223	238	253	253	181	115	158	92	135	69	112	46	89	23	41	109	82	109	41	0	23
59	178	193	193	206	216	216	231	246	246	261	276	276	204	138	181	115	158	92	135	69	112	46	64	114	82	109	41	23	0

An adjacency matrix of the recommended floor plan made by calculations of Floyd's Algorithm.

Proposed Floorplan
Adjacency Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
1	0	64																				64	45	45	49																																
2	64	0	26																					24			23																														
3		26	0	26																							38			30																											
4			26	0	26																									45			38																								
5				26	0	32																											53						30																		
6					32	0	32																																30					30													
7						32	0	26																																				30				56									
8							26	0	26																																							38			45						
9								26	0	26																																									30			30			
10									26	0	23																																											23			19
11										23	0	26																																											38		15
12											26	0	26																																										30	26	26
13												26	0	23																																									38	15	
14													23	0	26																																						23			19	
15														26	0	26																																		30			30				
16															26	0	26																														38			45							
17																26	0	32																							30						56										
18																	32	0	32																		30				30																
19																		32	0	26												53					30																				
20																			26	0	26								45			38																									
21																				26	0	26				38			30																												
22	64																				26	0	24			23																															
23	45																					24	0	53	30																																
24	45	24																					53	0	30																																
25	49																						30	30	0	32	32	19																													
26																					38	23			32	0	64	34																													
27		23	38																						32	64	0	34																													
28																									19	34	34	0	45	45	19																										
29																				45	30							45	0	86	45																										
30			30	45																								45	86	0	45																										
31																												19	45	45	0	56	56	19																							
32																			53	38											56	0	105	54																							
33				38	53																										56	105	0	54																							
34																															19	54	54	0	38	38									26												
35																																		38	0	75	53	30							38												
36																																		38	75	0			53	30					38												
37																		30	30																53		0	30																			
38																																			30		30	0			30	30															
39					30	30																														53			0	30																	
40																																				30			30	0			30	30													
41																	30	30																				30			0	53															
42																																						30			53	0	75		38	38											
43																																								30		75	0	53	38	38											
44						30	30																																	30			53	0													
45																																		26	38	38						38	38		0	26											
46																																										38	38		26	0	49	49	19								
47															38	56																														49	0	105	49								
48							56	38																																						49	105	0	49								
49																																														19	49	49	0	38	38	19					
50															30	45																																	38	0	75	38					
51								45	30																																								38	75	0	38					
52																																																	19	38	38	0	26	26	19		
53														23	30																																					26	0	56	30		
54									30	23																																										26	56	0	30		
55											38	30	38																																							19	30	30	0	23	23
56												26	15	19																																									23	0	36
57										19	15	26																																											23	36	0

A shortest-path matrix of the current floor plan made by calculations of Floyd’s Algorithm.

Proposed Floorplan
Shortest Path - All Vertices

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	64	90	116	142	174	206	232	245	245	253	245	253	245	245	232	206	174	142	116	90	64	45	45	49	81	81	68
2	64	0	26	52	78	110	142	168	194	220	242	234	242	234	234	234	223	205	173	147	124	101	77	24	54	86	23	57
3	90	26	0	26	52	84	116	142	168	194	217	233	241	233	233	233	222	215	184	161	140	124	100	50	70	102	38	72
4	116	52	26	0	26	58	90	116	142	168	191	213	238	231	231	231	220	213	196	176	161	147	126	76	96	124	64	90
5	142	78	52	26	0	32	64	90	116	142	165	187	212	215	215	215	233	228	211	196	184	173	152	102	122	150	90	116
6	174	110	84	58	32	0	32	58	84	110	133	155	180	184	196	208	226	241	228	213	215	205	184	134	154	182	122	148
7	206	142	116	90	64	32	0	26	52	78	101	123	148	152	164	188	210	226	233	220	222	223	215	166	185	200	154	166
8	232	168	142	116	90	58	26	0	26	52	75	97	122	126	138	164	188	208	215	231	233	234	226	192	196	211	180	177
9	245	194	168	142	116	84	52	26	0	26	49	71	96	100	112	138	164	196	215	231	233	234	226	218	196	211	206	177
10	245	220	194	168	142	110	78	52	26	0	23	45	70	74	100	126	152	184	215	231	233	234	226	226	196	211	211	177
11	253	242	217	191	165	133	101	75	49	23	0	26	52	70	96	122	148	180	212	238	241	242	234	234	204	219	219	185
12	245	234	233	213	187	155	123	97	71	45	26	0	26	45	71	97	123	155	187	213	233	234	226	226	196	211	211	177
13	253	242	241	238	212	180	148	122	96	70	52	26	0	23	49	75	101	133	165	191	217	242	234	234	204	219	219	185
14	245	234	233	231	215	184	152	126	100	74	70	45	23	0	26	52	78	110	142	168	194	220	226	226	196	211	211	177
15	245	234	233	231	215	196	164	138	112	100	96	71	49	26	0	26	52	84	116	142	168	194	218	226	196	206	211	177
16	232	234	233	231	215	208	188	164	138	126	122	97	75	52	26	0	26	58	90	116	142	168	192	226	196	180	211	177
17	206	223	222	220	233	226	210	188	164	152	148	123	101	78	52	26	0	32	64	90	116	142	166	215	185	154	200	166
18	174	205	215	213	228	241	226	208	196	184	180	155	133	110	84	58	32	0	32	58	84	110	134	184	154	122	182	148
19	142	173	184	196	211	228	233	215	215	215	212	187	165	142	116	90	64	32	0	26	52	78	102	152	122	90	150	116
20	116	147	161	176	196	213	220	231	231	231	238	213	191	168	142	116	90	58	26	0	26	52	76	126	96	64	124	90
21	90	124	140	161	184	215	222	233	233	233	241	233	217	194	168	142	116	84	52	26	0	26	50	100	70	38	102	72
22	64	101	124	147	173	205	223	234	234	234	242	234	242	220	194	168	142	110	78	52	26	0	24	77	54	23	86	57
23	45	77	100	126	152	184	215	226	226	226	234	226	234	226	218	192	166	134	102	76	50	24	0	53	30	47	62	49
24	45	24	50	76	102	134	166	192	218	226	234	226	234	226	226	226	215	184	152	126	100	77	53	0	30	62	47	49
25	49	54	70	96	122	154	185	196	196	196	204	196	204	196	196	196	185	154	122	96	70	54	30	30	0	32	32	19
26	81	86	102	124	150	182	200	211	211	211	219	211	219	211	206	180	154	122	90	64	38	23	47	62	32	0	64	34
27	81	23	38	64	90	122	154	180	206	211	219	211	219	211	211	211	200	182	150	124	102	86	62	47	32	64	0	34
28	68	57	72	90	116	148	166	177	177	177	185	177	185	177	177	177	166	148	116	90	72	57	49	49	19	34	34	0
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