GRAPHICAL INTERFACING TO A CONCEPTUAL MODEL FOR ESTIMATING THE COST OF RESIDENTIAL CONSTRUCTION

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ABSTRACT. This paper presents a method for determining elemental square foot costs and cost significance for residential construction. Using AutoCAD's 'icon menu' and 'dialogue box' facilities, a non-expert may graphically select (i) residential configuration; (ii) construction quality level; (iii) geographical location; (iv) square foot area; and finally, (v) add-ons, e.g. porches and decks, basement, heating and cooling equipment, garages and carports etc. in order to determine on-site builder's costs. Subsequent AutoLisp routines facilitate data transfer to a Lotus 1-2-3 spreadsheet where an elemental cost breakdown for the project may be determined. Finally, using Lotus 1-2-3 macros, computed data is transferred back to AutoCAD, where all cost significant items are graphically highlighted.

1. Introduction

Custom builders are often required to produce 'conceptual' cost estimates of houses for prospective clients. These are usually based on historical figures and presented to the client as a total project cost, e.g. $250,000 at $100 per square foot. Factors such as job complexity, quality, location, add-ons etc., are normally consolidated into the overall job price. Normally, the contractor does not provide a detailed elemental breakdown of these figures to the client. Hence, when changes to the original specifications and blueprints are requested, clients are usually unable to determine the impact of those changes on cost.

However, home builders typically determine the basic building costs by reference to tabulated in-house company records or by recourse to published data. For example, let us assume that the gross floor area of a proposed six-cornered single-family residence is 1567 square feet and that the construction quality level has been specified as 'good'. Then, by reference to, say, the Berger Cost Manual, Table 1, a cost per square foot of $49.46 may be determined, giving a conceptual basic cost to the client of (1567 * $49.46), or $77,504.

In addition, supplementary costs for add-ons, e.g. provision for basements, heating and cooling equipment, garages etc. may also be consolidated into the overall sum cost by incorporating extra line-item costs. Thus the home builder is able to determine a cost estimate for the builder's cost associated with a proposed house. These costs typically include all design fees and construction supervisory expenses, although the land value, builder's profit and additional cost associated with unusual site conditions are typically excluded.

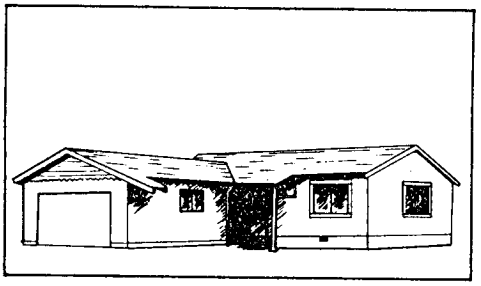
2. Cost Estimating by 'Rules-of-Thumb'

Once the residential contractor has determined a global construction cost for the project, a % elemental breakdown of costs may be produced. These %-cost 'rules-of-thumb' are typically tabulated according to historical company accountancy records (Table 2). When presented in a spreadsheet format, these figures may subsequently be used interrogatively in a 'what-if' mode, i.e. the (%) rule-of-thumb breakdown may be modified in order (i) to assess variations in

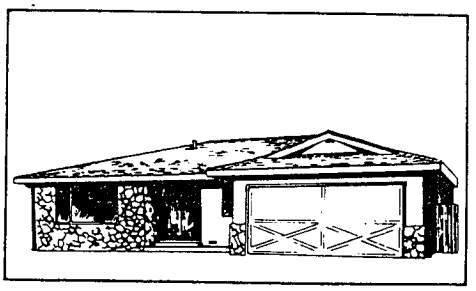
H. Timmermans (ed.), Design and Decision Support Systems in Architecture, 137–146.

subcontractor bid prices (+ or -) over anticipated costs, or (ii) to modify specific line items in terms of anticipated cost adjustments. In this way the home builder is able to validate subcontractor prices as well as establish company-specific broad-based elemental cost breakdown records.

TABLE 1. Single-family residences: six corners



Single Family Residence, Class 4



Single Family Residence, Class 2

	Square Foot Area										
Quality Class	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700
1, Best	74.03	70.48	67.70	65.44	63.58	62.01	60.67	59.52	58.51	57.62	56.83
1 & 2	68.05	64.79	62.22	60.15	58.44	57.00	55.77	54.71	53.78	52.96	52.23
2, Good	62.58	59.58	57.22	55.32	53.74	52.42	51.29	50.31	49.46	48.70	48.03
2 & 3	57.28	54.54	52.38	50.63	49.19	47.98	46.95	46.05	45.27	44.58	43.97
3, Average	52.26	49.75	47.78	46.19	44.88	43.77	42.83	42.01	41.30	40.67	40.11
3 & 4	47.11	44.86	43.08	41.65	40.46	39.47	38.61	37.88	37.24	36.67	36.17
4, Low	42.47	40.44	38.84	37.54	36.47	35.57	34.81	34.14	33.57	33.05	32.60

With his 'expert knowledge' of construction terminology and wealth of previous experience, the elemental cost breakdown spreadsheet may be relatively simple. However, if the system were to be used by a client, or 'non-expert', modifications to the current system would be necessary. The remainder of the paper describes how these amendments may be made to facilitate greater ease of operation for a 'non-expert' user.

TABLE 2. Elemental cost breakdown 'rules-of-thumb'

Rules-of-Thumb (RoT) Cost Breakdown			
ITEM	RoT %	Unit Cost 100% ITEM COST ($)	Atlanta Cost 79% ATLANTA COST ($)
Excavation	0.70%	$1,610	$1,272
Flatwork (drive & walk)	1.40%	$3,219	$2,543
Foundation, slab, piers	2.10%	$4,829	$3,815
Brick hearth & veneer	0.40%	$920	$727
Rough hardware	0.20%	$460	$363
Finish hardware	0.10%	$230	$182
Rough lumber	4.25%	$9,773	$7,720
Finish lumber	0.25%	$575	$454

Rules-of-Thumb (RoT) Cost Breakdown

ITEM	RoT %	Unit Cost 100% ITEM COST ($)	Atlanta Cost 79% ATLANTA COST ($)
Rough carpentry labour	4.75%	$10,922	$8,629
Finish carpentry labour	1.00%	$2,299	$1,817
Counter-tops	1.00%	$2,299	$1,817
Cabinets	2.00%	$4,599	$3,633
Insulation (R19 ceiling)	1.30%	$2,989	$2,362
Roofing	3.25%	$7,473	$5,904
Painting	2.50%	$5,749	$4,541
Shower & tub enclosure	0.30%	$690	$545
Prefabricated fireplace	0.15%	$345	$272
Bath accessories	0.20%	$460	$363
Built-in appliances	0.50%	$1,150	$908
Heating and ducting	2.75%	$6,324	$4,996
Plumb. & sewer connect	4.25%	$9,773	$7,720
Doors	1.25%	$2,874	$2,271
Garage door	0.25%	$575	$454
Alum. windows, door	0.75%	$1,725	$1,362
Exterior stucco	3.75%	$8,623	$6,812
Gypsum wallboard	2.50%	$5,749	$4,541
Resilient flooring	1.15%	$2,644	$2,089
Carpeting	1.50%	$3,449	$2,725
Wiring (Romex)	1.75%	$4,024	$3,179
Lighting fixtures	0.75%	$1,725	$1,362
Insurance, payroll tax	1.50%	$3,449	$2,725
Plans and specs	0.25%	$575	$454
Permits & utilities	1.00%	$2,299	$1,817
Final cleanup	0.25%	$575	$454
Total builder percentage	50.00%	$114,973	$90,829
Materials	34.0%	$78,182	$61,764
On-site labour	16.0%	$36,791	$29,065
Land and site improvements	25.0%	$57,487	$45,414
Sales and marketing	5.0%	$11,497	$9,083
Financing	8.0%	$18,396	$14,533
Overhead	7.0%	$16,096	$12,716
Profit	5.0%	$11,497	$9,083
Developer's sale price=	100.0%	$229,946	$181,657

3. AutoCAD to Lotus 1-2-3 Interface

Using AutoCAD as the primary interface to present data choices and to report cost significance provides several key benefits to non-expert users. For instance, (i) input data may be represented graphically; (ii) data transfer may be facilitated by simple AutoLisp routines; (iii) early cost estimates may become a powerful tool in determining likely cost projections for the project; and, finally, (iv) amendments to the building design may be automated.

Some of the steps taken in arriving at the model are enumerated below:

STEP 1. Create AutoCAD drawing files, including associated attribute data, for each residence configuration and add-on.

STEP 2. Use the AutoCAD BLOCK command to SAVE each named drawing file.

STEP 3. Create an ASCII template file that will control the (i) drawing data extraction, (ii) output data format, and (iii) field spacing.

STEP 4. Extract component data from the AutoCAD drawing file.

STEP 5. Integrate the Lotus 1-2-3 spreadsheet program with AutoCAD.

STEP 6. Set up spreadsheet facility to accept data from AutoCAD, import square foot cost data, and compute elemental construction costs in Lotus 1-2-3.

STEP 7. Establish Lotus 1-2-3 macros to automate data manipulation.

STEP 8. Send the spreadsheet data file back to AutoCAD using an AutoLISP routine to facilitate identification of cost-significant items.

This may be illustrated by reference to Figure 1.

4. Creating Icon Menus

4.1. AutoCAD slide libraries

Icon menus help in the selection of the residence configuration, add-ons and other cost-related items. Icon menus use slide libraries that are created by using AutoCAD's SLIDELIB.EXE program. Before invoking SLIDELIB.EXE, the user first makes all the required slides. This is done by invoking AutoCAD's MSLIDE command followed by a file name. Each slide represents a pre-drawn block, e.g. a construction element, equipment, symbol etc. The suffix DWG is automatically added to each file name. Continuing, an ASCII text file is created. The text file lists each slide name on a separate line. Care must be exercised not to include extra <returns> or <spaces> in the text file. Finally, SLIDELIB.EXE program is executed. The resulting slide file will contain a snapshot of the drawing displayed on the AutoCAD drawing screen. Slide files created are automatically given the file extension SLD, e.g. SLIDELIB ST < STYPE creates a slide library called ST from the ASCII list file STYPE.

4.2. Icon libraries

An icon menu is written in a manner similar to other pull-down menus except for its labels. That

is, the user needs to load the device with a $I=pagename and then display it with a $I=*. However, icons use the label [ ] to identify the name of the slide to show in the box. Each label corresponds to one label on the screen. These boxes are automatically arranged in groups of 4, 9, and 16. If the label is in the form of libraryname(slidename), then the named slide from the library will be displayed as an icon.

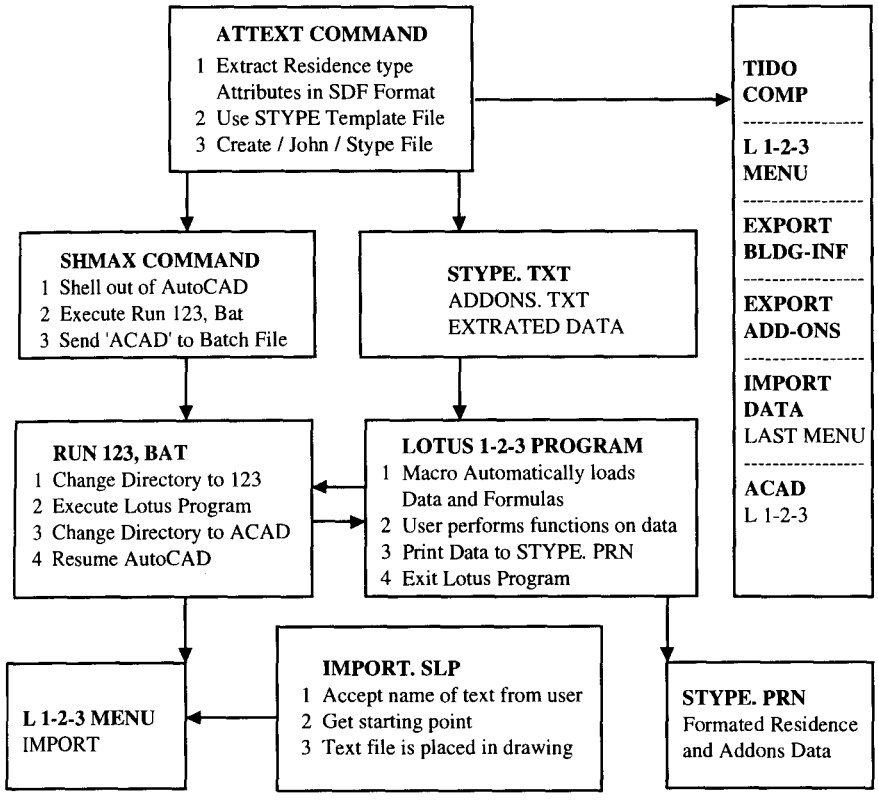


Figure 1. General flow diagram of problem solution

For example, the syntax for displaying ST may be added to ACAD.MNU, e.g.

```
***ICON
**ST
[JOHN WINDOWS]
[st(4-corn)]^c^cinsert 4-corn \;;;zoom e;zoom .9x;^c$s=wspecs
[st(6-corn)]^c^cinsert 6-corn \;;;zoom e;zoom .9x;^c$s=wspecs
[st(8-corn)]^c^cinsert 8-corn \;;;zoom e;zoom .9x;^c$s=wspecs
[st(10-corn)]^c^cinsert 10-corn \;;;zoom e;zoom .9x;^c$s=wspecs
[ close]^c^c$s=
```

For example, Figure 2, displays the residence configuration and add-on icon menus.

7. Sample Problem

7.1. INSIDE AUTOCAD

STEP 1. Pick from the screen menu RES-CONF.
STEP 2. List of drawing icons is displayed.
STEP 3. Pick a house floor plan, e.g. 4-cornered, 6-cornered etc.
STEP 4. Initially, accept all the defaults.
STEP 5. Dialogue box displays data. Data may be edited at this stage.
STEP 6. Select data transfer icon. Data is automatically transferred to Lotus 1-2-3.

7.2. INSIDE LOTUS 1-2-3

STEP 1. Enter / (slash) to obtain main Lotus 1-2-3 menu.
STEP 2. Select FR (File Retrieve), named file BUDGET.WK1.
STEP 3. Press <ALT>I. Lotus 1-2-3 macro that updates the spreadsheet finds the last line of text brought in from the import command; positions the cursor at the range location STYPE and imports the file; a DATA PARSE format string is created; input and output ranges are identified and the data is parsed.
STEP 4. Add-on data allocated.
STEP 5. Cost-significant items determined.
STEP 6. Print spreadsheet.
STEP 7. SQ (Save and Quit)

7.3. RETURN TO AUTOCAD

STEP 1. Select [IMPORT DATA] from custom side menu.
STEP 2. From prompt, select name of Lotus 1-2-3 file to import.
STEP 3. Review data, and repeat iteration as necessary.

Table 3 shows the elemental cost breakdown returned to AutoCAD with each element highlighted either as a significant or non-significant cost item.

TABLE 3. Significant and non-significant cost elements

ITEM		
Excavation	$1,272	Non-significant
Flatwork (drive & walk)	$2,543	Non-significant
Foundation, slab, piers	$3,815	Significant
Brick hearth & veneer	$727	Non-significant
Rough hardware	$363	Non-significant
Finish hardware	$182	Non-significant
Rough lumber	$7,720	Significant
Finish lumber	$454	Non-significant
Rough carpentry labour	$8,629	Significant
Finish carpentry labour	$1,817	Non-significant
Counter-tops	$1,817	Non-significant
Cabinets	$3,633	Significant
Insulation (R19 ceiling)	$2,362	Non-significant

ITEM		
Roofing	$5,904	Significant
Painting	$4,541	Significant
Shower & tub enclosure	$545	Non-significant
Prefabricated fireplace	$272	Non-significant
Bath accessories	$363	Non-significant
Built-in appliances	$908	Non-significant
Heating and ducting	$4,996	Significant
Plumb. & sewer connect	$7,720	Significant
Doors	$2,271	Non-significant
Garage door	$454	Non-significant
Alum. windows, door	$1,362	Non-significant
Exterior stucco	$6,812	Significant
Gypsum wallboard	$4,541	Significant
Resilient flooring	$2,089	Non-significant
Carpeting	$2,725	Non-significant
Wiring (Romex)	$3,179	Significant
Lighting fixtures	$1,362	Non-significant
Insurance, payroll tax	$2,725	Significant
Plans and specs	$454	Non-significant
Permits & utilities	$1,817	Non-significant
Final cleanup	$454	Non-significant
Total builder percentage	$90,829	

8. Discussion

8.1. EXPERT KNOWLEDGE

No two computer-aided drafting (CADr) programs are identical, and their capabilities and ease of operation vary greatly. However, ease of use can be improved with most CADr packages by customizing the user interface. This can be done by modifying the manner in which commands are accessed to the program. This has been clearly demonstrated with the conceptual estimating routines described above. By modifying the AutoCAD default screen and pull-down menus, as well as introducing custom icon menus and dialogue boxes, non-expert CAD users are able to work interactively with a relatively complex cost model.

The user first selects from the floor plan icon menu the building layout that characterizes the proposed house, e.g. four-cornered, six-cornered etc. A dialogue box requests the user to specify the overall gross floor area and construction quality for the dwelling. Subsequently, the user is required to specify all add-ons. Finally, the user simply selects the 'export' data icon. The data is then transferred to Lotus 1-2-3. Lotus 1-2-3 macros are invoked, initially setting a @Lookup operation to determine the square foot cost given the house complexity (in terms of configuration) and specified construction quality. Continuing, the elemental cost breakdown routine is activated, thus enabling a conceptual cost breakdown for the project to be determined. Lastly, cost significance is established. The rules for cost significance are relatively simple, i.e. the mean cost of all construction elements is calculated. If the sum cost of each construction element is

determined to be greater than the mean value, then that element is deemed to be cost-significant. This information is then transferred back to AutoCAD, where a listing of significant and non-significant cost items are depicted on the screen.

The cost model described in the paper is not complex. However, it does demonstrate the advantages of linking compatible software. Further work in the field is under investigation in order to (i) allow for different construction forms, e.g. commercial, industrial etc.; (ii) accommodate actual CAD construction plans (other than the current simple icon configurations); and (iii) link with more complex cost estimation models.

References

Gibson, S. (ed.), (*1990) Berger Cost Manual*, Craftsman Books, Hongkong.