

Appendix B: Glossary

- ‘←’: The “escape” character number 27, used in files for input redirection. See the section **Input redirection** in chapter 4.
- ←: The cursor control key with an arrow pointing left. On many keyboards this is on the numeric keypad, under the number 4. This is not the same as the Backspace key. In a horizontal menu, it moves the bar to the left. When input is requested from the keyboard, it moves the cursor to the left (unless it is already at the start of the input area).
- : The cursor control key with an arrow pointing right. On many keyboards this is on the numeric keypad, under the number 6. In a horizontal menu, it moves the bar to the right. When input is requested from the keyboard, it moves the cursor to the right (unless it is already at the end of what you have typed).
- ↑: The cursor control key with an arrow pointing up. On many keyboards this is on the numeric keypad, under the number 8. This is not the same as the shift keys. In a horizontal menu, it scrolls one line up in the screen (recalling the last line that disappeared at the top of the screen). In a vertical menu, it moves the bar one line up. When input is requested from the keyboard, it recalls the last line you entered.
- ↓: The cursor control key with an arrow pointing down. On many keyboards this is on the numeric keypad, under the number 2. In a horizontal menu, it scrolls one line down in the screen. In a vertical menu, it moves the bar one line down.
- ↵: The Backspace key. When input is requested from the keyboard, it deletes the character to the left of the cursor.
- ↩: The large key, usually called ‘Return’ or ‘Enter’, in the same position as the carriage return on a typewriter keyboard. In a menu, it chooses the item currently in the reverse- video bar. It ends a line of input requested from the keyboard and sends it to LINEAR.
- “”’: In a problem file, starts or ends an echoed comment.
- ‘*’: In the variables declaration or tableau, indicates an artificial variable. In an arithmetic expression, the symbol for multiplication (which may be omitted).
- .arf**: Suggested extension for an “Automatic Response File” used in input redirection.
- .dif**: Default extension for a DIF file.
- .prb**: Default extension for a problem file.
- .res**: Default extension for an output file produced using ‘Record’.
- .tab**: Default extension for a TAB file.
- ‘;’: Used to separate the parts of a problem file.
- ‘<’: Used by LINEAR as an abbreviation of ‘<=’.
- ‘<=’: Less than or equal to.
- ‘>’: Used by LINEAR as an abbreviation of ‘>=’.
- ‘>=’: Greater than or equal to.
- ‘?’: In a problem file, indicates that the value of this parameter is to be entered by the user.
- ‘[’: In a problem file, starts the name of the objective function or a constraint.
- ‘!’: In a problem file, starts a non-echoed comment.
- ‘]’: In a problem file, ends the name of the objective function or a constraint.
- ‘^’: In an arithmetic expression, the symbol for “power” (A^B means A^B). The value of A must be positive, and $B \ln(A) \leq 87$, else an error will result.
- 8087, 80287, 80387**: Intel coprocessor chips, available as optional equipment on most computers of the IBM PC family and compatibles, allowing high-speed floating-point arithmetic.

abs: The absolute value function: $\text{abs}(x) = x$ if $x \geq 0$, $-x$ if $x \leq 0$.

all-integer: A problem in which all the variables (including slack variables) must have integer values.

append: Add further information to the end of a file.

arctan: The inverse tangent function (using radians): $\text{arctan}(x) = y$ if $\tan(y) = x$ and $-\pi/2 < y < \pi/2$.

artificial variable: A variable which must be zero in order for a solution to be feasible. In LINEAR, these arise in three ways: as the difference between the two sides of an equality constraint, as a name preceded by '*' in the variables declaration, and in the command 'Change Delete Variable'. LINEAR indicates them with 'ARTIF' before the name, except in 'Show tableau' where they are indicated with '*'.

Automatic Response File: A file used as a source for redirected input. It must contain all the keystrokes that would otherwise have been typed at the keyboard.

AUX: Same as COM1:

back up: Make a copy of (a file), as protection in case the original is damaged. Highly recommended for both programs and data.

bar: A rectangle in a menu, in which text is reverse-video: black on white instead of white on black. May be moved to the item you wish to choose.

basic feasible solution: Basic solution which is feasible.

basic solution: Solution obtained by setting all the nonbasic variables of a tableau to 0. May or may not be feasible or optimal.

basic variable: In a tableau, a variable whose value is expressed in terms of the nonbasic variables. In the basic solution corresponding to the tableau, such a variable may have a nonzero value.

basis: The collection of basic variables.

batch mode: Automatic execution of programs without intervention from the keyboard. This can be done for LINEAR by input redirection.

Begin skip: See skip.

binding: Describes a constraint whose slack variable is nonbasic.

buffer: See dialog buffer.

BW80: Display mode consisting of 80 columns and 25 rows of text, with color disabled. This is necessary for some monitors, on which color produces a mottled effect. It can be selected in the configuration file LINEAR.CFG.

character: A letter, digit, blank space, symbol or control character. It may be typed at the keyboard or appear in a file or on the screen.

close: Procedure done to a file when the program is finished reading or writing it. If you use 'Record' to send data to a disk file, this will not be done until you choose 'Record' again or quit LINEAR. If you take out the disk or turn off the computer before this happens, you may lose data.

CO80: Display mode consisting of 80 columns and 25 rows of text, with color enabled. This is the default mode for LINEAR. It can be changed in the configuration file LINEAR.CFG.

coefficient: A number, or an expression with a numerical value, that multiplies a variable in a constraint or objective function. The coefficient must come before the variable.

COM1: The first serial port.

command: A choice in a menu, telling LINEAR to do something.

command line: The line by which LINEAR was invoked from DOS.

CON: Identifies input that comes directly from the keyboard, rather than from a disk file.

configuration file: A file containing information on some adjustable settings, which is read when a program is loaded. For **LINEAR** this file is **LINEAR.CFG**. See the section **Configuring LINEAR** in Chapter 4.

constant: A fixed numerical value.

constraint: An equality or inequality which solutions of a linear programming problem must satisfy.

constraints declaration: Part of a problem file declaring the number of constraints. It consists of the word 'constraints', the number of constraints and a semicolon.

coprocessor: A chip such as the Intel 8087, performing high-speed floating-point arithmetic.

cos: The cosine function, using radians.

Ctrl Break : Key combination to stop runaway output and return you to the main menu.

Ctrl Num Lock : Key combination which suspends screen output until another key is pressed.

Ctrl PrtSc : Key combination acting as a toggle switch for echoing screen output (except menus) to the printer.

Ctrl S : Key combination which, on some machines, suspends screen output until another key is pressed.

current directory: The directory that will be used in finding files when no directory is explicitly indicated. DOS maintains one current directory on each drive. It can be changed by the '**File Path**' command.

cutting plane: A constraint which can be added to an integer programming problem. Any feasible solution in integers would satisfy this constraint, but the current basic solution does not.

cycling: A situation in which a sequence of degenerate pivots repeat in an endless loop. This is the only way that the Simplex Method can fail to produce the optimal solution. If this threatens to occur in **LINEAR**, you can use the '**Change Add Perturbation**' command to remove the degeneracy.

data parameter: A parameter listed in the **parameters declaration** of a problem file. Its value is specified there, computed from an expression involving other parameters, or input from the keyboard when the file is loaded.

decision variable: A variable which is part of the original statement of the problem.

default drive: The disk drive that will be used in finding files when no drive is explicitly indicated. This is usually indicated in the DOS prompt. It can be changed by the '**File Path**' command.

default extension: Extension added by **LINEAR** to a file name entered without a period: '**.dif**', '**.prb**', '**.res**' or '**.tab**', depending on the type of file.

default name: A name used by **LINEAR** if none is provided by the user or input file. For files of a given type, the default name is initially '*' followed by the default extension for that type; whenever a file name of that type is chosen, it becomes the default. It is shown in square brackets when you are prompted for a file name. For the objective function, the default name is '**OBJECTIVE**'. For a constraint, the default name consists of '**C_**' followed by the number of the constraint.

default response: Shown in square brackets when you are prompted for input. This will be used if you just press **↵** without typing anything.

degeneracy: The situation where some basic variables in a basic solution have the value zero. In this case there may be more than one basis corresponding to the same basic solution. A pivot may go from one of these bases to another without changing the basic solution.

degenerate pivot: A pivot in which the basic solution does not change. The variable leaving the basis already had the value zero, and the entering variable will still be zero.

Del : Cursor control key: on many keyboards it is on the numeric keypad, under the decimal point. When input is requested from the keyboard, it deletes the character the cursor is on.

dialog buffer: Area of memory containing up to 819 lines of screen output (not including menus).

In any horizontal menu, the **↑**, **↓**, **Home**, **End**, **PgUp** and **PgDn** keys scroll through the buffer. The size of the buffer can be set using `LINEAR.CFG`.

dictionary: A set of equations expressing the objective function and basic variables in terms of the nonbasic variables.

DIF: A standard file format allowing unrelated programs to share data. Supported by many spreadsheets and databases, as well as by `LINEAR`.

directory: A subdivision of a disk, which may contain files.

distribution disk: The floppy disk forming part of this package, containing the `LINEAR` programs and related files.

drive: Identifier for a disk drive, e.g. 'A:'.

dual problem: To each linear programming problem there corresponds another linear programming problem. The first is called the **primal** problem and the second is called the **dual** problem. Rows of the primal tableau correspond to columns of the dual tableau, and columns of the primal to rows of the dual. The simplex method solves both problems at the same time.

dual variable: A variable of the dual problem. Decision variables of the primal correspond to slack variables of the dual, and slack variables of the primal correspond to decision variables of the dual. A primal variable is basic if and only if the corresponding dual variable is nonbasic. The values of the basic dual variables are the shadow prices of the corresponding nonbasic primal variables.

echoed comment: In a problem file, anything between quotation marks `""`. When the file is loaded, this will be shown on the screen.

EGA: This type of display card allows a display mode with 43 rows of text, rather than the usual 25. That mode is selected if `'EGA'` is given as the display mode in the configuration file `LINEAR.CFG`.

end: Indicates the end of a problem file.

End : Cursor control key: on many keyboards it is on the numeric keypad, under the number 1. When input is requested from the keyboard, it moves the cursor to the end of the input area. In a horizontal menu, it scrolls to the end of the dialog buffer.

End skip: See `skip`.

enter: Type at the keyboard, and press **↵**.

enters the basis: Refers to a variable which was nonbasic before a pivot and becomes basic.

equality: A constraint of the form $A = B$.

error message: A message appearing on the screen, signalling that an error has occurred. A fuller explanation of the error can be obtained by choosing `'Explain'`.

Esc : Pressing this key will take you to the main menu from any other menu or when asked for input.

exp: The exponential function: $\exp(x) = e^x$ where $e = 2.71828\dots$ is the base of natural logarithms. An overflow error will occur if $x > 87$.

expression: In a problem file, a quantity written down using the operations of arithmetic and the functions 'abs', 'arctan', 'cos', 'sin', 'exp', 'ln', 'sqrt', 'round', 'max', and 'min' with numbers and parameters. This may be used as the value of a parameter, or instead of a number in the objective or a constraint.

explicit basis: Format for a tableau in which every variable labels a column. See **implicit basis**.

extension: Up to three characters following a period at the end of a file name, usually indicating the type of file. If a file name with no period is entered, LINEAR supplies the default extension for the type of file: '.dif', '.prb', '.res' or '.tab'.

F1 : Press this function key to see a brief explanation of the menu item currently in the reverse-video bar, or the input being requested.

feasible solution: A solution in which all variables have values ≥ 0 , and all artificial variables have value 0. This satisfies all the constraints of the problem, but may or may not be optimal.

file name: The name of a disk file may consist of up to 8 characters, followed optionally by a period and a 3-letter extension. If no period is present, LINEAR will add a default extension.

free variable: A variable which is allowed to have any sign. LINEAR does not allow these. Instead of a free variable, use the difference of two variables.

header lines: Preliminary information or titles produced by various commands. If 'Headers' is set to OFF by the 'Options' command, these will not be sent to output files produced by 'Record', allowing such files to be used by database programs without editing.

help: LINEAR provides on-line explanations for all menu choices and keyboard inputs, available by pressing **F1**. In a menu, move the bar to the choice you want explained before you press **F1**.

Home : Cursor control key: on many keyboards it is on the numeric keypad, under the number 7. When input is requested from the keyboard, it moves the cursor to the beginning of the input area. In a horizontal menu, it scrolls to the beginning of the dialog buffer.

implicit basis: Format for a tableau in which only nonbasic variables label columns, while the objective and basic variables label rows. LINEAR uses this format.

inequality: A constraint of the form ' $A \geq B$ ' or ' $A \leq B$ '.

infeasible: A problem with no feasible solutions. It is impossible to satisfy all the constraints.

input redirection: The DOS facility that causes a program to take its input from a file or device rather than from the keyboard. It is invoked by placing '<' and the name of a file on the command line. See the section **Input redirection** in chapter 4.

Ins : Cursor control key: on many keyboards it is on the numeric keypad, under the number 0. When input is requested from the keyboard, it toggles between "insert" and "overwrite" modes.

insert mode: When input is requested from the keyboard, in this mode any characters at and to the right of the cursor are pushed to the right as you type. It is indicated by a fat cursor. Press **Ins** to toggle between this and "overwrite mode".

integer: A whole number.

integer forms: Method of producing cutting planes for all-integer linear programming problems.

integer programming: Optimization in which some or all variables are required to take integer values.

interactive: Allowing the active participation of the user.

leaves the basis: Refers to a variable which was basic before a pivot and becomes nonbasic.

- linear constraint:** An equality or inequality between two linear functions.
- linear function:** A term or sum of terms, each of which is either a constant, a variable, or a constant times a variable.
- linear programming:** Optimization of a linear objective function of several variables, subject to linear constraints.
- LINEAR.CFG:** File containing configuration information for LINEAR. This consists of the screen mode, the size of the dialog buffer, the paths for LINEAR.HLP and data files, and the settings 'Decimals', 'Show pivots' and 'Keep artificials'. See the section **Configuring LINEAR** in Chapter 4.
- LINEAR.EXE:** File containing the LINEAR program (in the version not requiring a math coprocessor). To run it, enter `linear` at the DOS prompt.
- LINEAR.HLP:** File containing on-line help and error messages.
- ln:** The natural logarithm function. Its argument must be a positive number.
- load:** Produce the internal representation of a problem by reading a file or taking input from the keyboard.
- LPT1:** The first parallel printer.
- math coprocessor:** See **coprocessor**.
- max:** At the start of the objective declaration, an abbreviation for "maximize". Otherwise a function of any number of variables: $\max(x_1, \dots, x_n)$ is the greatest of x_1, \dots, x_n .
- maximize:** Obtain the greatest possible value of (a function).
- menu:** A list of possible choices to determine what will happen next.
- method of integer forms:** Method of producing cutting planes for all-integer linear programming problems.
- min:** At the start of the objective declaration, an abbreviation for "minimize". Otherwise a function of any number of variables: $\min(x_1, \dots, x_n)$ is the least of x_1, \dots, x_n .
- minimize:** Obtain the least possible value of (a function).
- mnemonic:** Easily remembered, or providing a clue to remind people of its meaning. A good characteristic for variable and constraint names.
- name:** The name of a variable, constraint, objective or parameter may have any length, but only the first 11 characters are recognized. It must start with a letter, and may include letters, digits and the underscore '_'. The name of the objective or a constraint is given in brackets '[''] before the concluding semicolon. If no name is provided in the problem file, LINEAR will supply a name: 'OBJECTIVE' for the objective, 'C_' and a number for a constraint.
- nonbasic variable:** In a tableau, the basic variables are expressed in terms of the nonbasic variables. In the basic solution corresponding to the tableau, all nonbasic variables have the value 0.
- non-document mode:** In some word processors, an option which will produce ordinary text files without special formatting characters. If present, it should be used when producing problem files for LINEAR.
- non-echoed comment:** In a problem file, anything that follows '!' until the end of a line. LINEAR ignores these completely.
- Num Lock:** A key which toggles the numeric keypad between cursor control (when off) and numerical input (when on).
- objective:** Same as **objective function**.

- objective declaration:** Part of a problem file, consisting of the word ‘maximize’ or ‘minimize’, the objective function, (optionally) the name of the objective enclosed in square brackets, and a semicolon.
- objective function:** The quantity that is to be maximized or minimized in a linear programming problem, expressed as a linear function of the variables.
- objective parameter:** A parameter affecting the objective function. In LINEAR, the ‘**Analyze Objective**’ command can study the effects of these.
- objective ranging:** Finding the amount by which a coefficient in the objective function could change while keeping the current basic solution optimal. LINEAR does this for all decision variables with the command ‘**Values Ranging Objective**’.
- objective row:** The row of a tableau representing the objective function.
- optimal solution:** A feasible solution of the problem, such that there is no feasible solution with a better value of the objective function.
- optimize:** Obtain the best (greatest or least) possible value of (a function).
- overwrite mode:** When input is requested from the keyboard, in this mode any characters at and to the right of the cursor stay in place and are overwritten as you type. It is indicated by a thin cursor. Press **Ins** to toggle between this and “insert mode”.
- parameter:** A named quantity which is used in expressing the problem, but is not a variable (and thus its value is not determined by LINEAR). There are three types: **data parameters**, **objective parameters** and **rhs parameters**.
- parameters declaration:** An optional part of a problem file, coming between the constraints declaration and the variables declaration. It consists of the word ‘**parameters**’ followed by the number of parameters, the list of parameters and values, and finally a semicolon.
- parametric programming:** Finding how the optimal solution depends on the value of a parameter. In LINEAR, this is done with the ‘**Analyze**’ command for objective and rhs parameters.
- perturbation:** A small change in a quantity. LINEAR’s command ‘**Change Add Perturbation**’ makes small random changes in the RHS column to remove degeneracy and prevent cycling.
- PgDn**: Cursor control key: on many keyboards it is on the numeric keypad, under the number 3. In a horizontal menu, scrolls one screen down towards the end of the dialog buffer. In the vertical menu for choosing a file, if more than 22 matching files have been found, scrolls one screen down towards the end of the list of matching files. Otherwise moves the bar to the bottom of a vertical menu.
- PgUp**: Cursor control key: on many keyboards it is on the numeric keypad, under the number 9. In a horizontal menu, scrolls one screen up towards the beginning of the dialog buffer. In the vertical menu for choosing a file, if more than 22 matching files have been found, scrolls one screen up towards the beginning of the list of matching files. Otherwise moves the bar to the top of a vertical menu.
- Phase 0:** Stage of LINEAR’s method of solving problems, during which it removes artificial variables from the basis.
- Phase 1:** Stage of LINEAR’s method of solving problems, during which it seeks a basic feasible solution.
- Phase 2:** Final stage of LINEAR’s method of solving problems, during which feasibility is maintained while an optimal solution is sought.
- pivot:** An operation which transforms one tableau into another, one basic variable becoming nonbasic and one nonbasic variable becoming basic.

post-optimality analysis: See **sensitivity analysis**.

PRN: Same as ‘**LPT1**’.

problem file: A text file expressing a linear programming problem in a format acceptable to LINEAR, and similar to what you would write down on paper.

prompt: A message asking you to enter something from the keyboard. In a problem file, echoed comments should be used as prompts for parameter values.

ranging: A part of sensitivity analysis. Finding the amount by which an objective coefficient or right-hand-side entry could change while keeping the current basis optimal. The ‘**Values Ranging**’ command does this in LINEAR.

real number: Mathematically, any number represented by a point on a number line. In LINEAR, its absolute value must be from approximately 5×10^{-307} to $1 \times 10^{+308}$, and about 16 significant digits are kept.

redirection: The DOS facility allowing a program to obtain its input from a file instead of the keyboard, or send output to a file instead of the screen. You can redirect LINEAR’s input, but not its output. See the section **Input redirection** in chapter 4.

reduced cost: Same as **shadow price**.

rewrite: Erase a file, and prepare a new file of the same name for output.

RHS: Abbreviation of “right-hand-side”. The column of a tableau containing the constant terms.

RHS parameter: A parameter affecting the constants column of a problem. In LINEAR, represented by an artificial variable for use with the ‘**Analyze Rhs**’ command.

RHS ranging: Finding the amount by which a right-hand-side entry could change while keeping the current basis optimal. LINEAR does this for all constraints with the command ‘**Values Ranging Rhs**’.

right-hand-side: See **RHS**.

round: The function that rounds a real number to the nearest integer: $\text{round}(x) = n$ if n is an integer and $n - 1/2 \leq x < n + 1/2$.

save: Produce a file containing a representation of the problem as it currently exists in the computer’s memory.

sensitivity analysis: The study of what would happen to the optimal solution to a problem as a result of small changes in the problem.

shadow price: (of a nonbasic variable) The tableau entry in the objective row and the column labelled by the variable. It represents the cost per unit of small increases in that variable.

Shift PrtSc: Key combination for sending a “snapshot” of the current screen to the printer.

SideKick: A product of Borland International, Inc. Its most useful feature for LINEAR is a resident notepad editor, which allows you to edit problem files without leaving LINEAR.

sign-free: See **free variable**.

Simplex Method: Method of solving linear programming problems by successive pivot operations. LINEAR uses a version of this method.

sin: The sine function, using radians.

skip: When LINEAR encounters an error in a problem file, it sometimes abandons further processing of the objective function or constraint and skips to the next semicolon. When it finds that semicolon, LINEAR signals ‘**End skip**’ (this is not another error message).

slack variable: The difference between the two sides of an inequality constraint, which must not be negative in order for a solution to be feasible. LINEAR automatically creates these variables when loading a problem, and indicates them with ‘**SLACK**’ and the name of the constraint.

- solution:** A set of values for the variables and objective function, satisfying the equations of the tableau. It may or may not be feasible or optimal.
- sqrt:** The square root function. Its argument must be a number ≥ 0 .
- TAB:** Type of file, produced by the '**File Save Tab**' command, containing an exact image of the state of the problem in memory. May later be used by the '**File Load Tab**' command to restore that state.
- tableau:** An array of numbers, representing a set of equations (dictionary) expressing the objective and basic variables in terms of the nonbasic variables.
- unbounded:** A problem having feasible solutions with arbitrarily large values (positive for a maximization problem, or negative for minimization) of the objective. Therefore there is no optimal solution.
- variable:** A named quantity whose value is determined by solving a linear programming problem. There are **decision variables**, which are part of the statement of the problem, and **slack** and **artificial variables**, which correspond to inequality and equality constraints respectively. In LINEAR, for a solution to be feasible each variable's value must be a nonnegative real number, except for artificial variables which must be zero. See **artificial variable**, **decision variable**, **slack variable**.
- variables declaration:** Part of a problem file containing the number and list of variables. It consists of the word '**variables**', the number of variables, a list of all variables used, and a semicolon.
- VGA:** This type of display card with an analog monitor allows a display mode with 50 rows of text, rather than the usual 25. That mode is selected if '**VGA**' is given as the display mode in the configuration file LINEAR.CFG.
- wild cards:** The characters '*' and '?' in file names. '?' can stand for any character. '*' can stand for any string of characters.