

Opturion Production Planning and Scheduling – Data Formats

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OPTURION

Intelligent Decision Support

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1 Overview

The Opturion Production Planning and Scheduling optimiser (PPS) builds production plans and schedules for make-to-order manufacturing and other multi-step processing operations. It takes a set of orders, each of which must be processed through a sequence or network of operations, together with a description of the resources (machines, work centres, bays, cells), the staff and the working time that are available to do that work. It decides when, and on which resources, each operation is carried out so as to complete as many orders as possible by their due dates.

The PPS has two modes of operation:

1. *Scheduling*: the PPS builds a detailed schedule giving the start and finish time, the resource and the staff for every operation. Scheduling takes account of resource capacities and calendars, staff skills and rosters, set-up and changeover times, shutdowns, maintenance and the progress of work that is already under way.
2. *Planning*: the PPS builds a rough-cut capacity plan, assigning each operation to a time bucket (typically a week) and comparing the resulting load against the capacity of each resource. Planning is much faster than scheduling and is intended for answering questions such as "can we accept this order and still meet its due date?" or "which work centres will be overloaded next month?". It can include potential orders (quotes) weighted by their probability of being won.

This document describes the data model used by the PPS and the Microsoft Excel formats for its input (Section 4) and output (Section 5). A set of example workbooks that illustrate each feature in turn is described in Appendix A.

2 Concepts and Data Model

This section describes the major concepts in the PPS data model. Section 4 describes how they are represented in Excel.

2.1 Scenarios

An input to the PPS is called a *scenario*. It is a description of the planning or scheduling problem to be solved and consists of:

1. a configuration, including the planning horizon;
2. a set of resources;
3. a set of routings describing the operations needed to make each kind of product;
4. a set of orders;

and, optionally:

5. shifts and shift patterns that define working time;
6. staff and their skills and absences;
7. set-up and changeover times;
8. shutdowns and maintenance;
9. order-specific operation data and order precedences;
10. the status and progress of work already under way;
11. resource capacities for planning.

2.2 Solutions

A *solution* is a schedule or plan created by the PPS. In scheduling mode it gives the resource, staff and start and finish times of each operation. In planning mode it gives the time bucket and resource of each operation and the resulting load on each resource in each time bucket. In both modes it reports the expected completion time and lateness of each order, and lists any orders that could not be scheduled together with the reason why.

2.3 Identifiers

Entities in a scenario, such as resources, routings, orders and staff, must each have a unique *identifier* (Id) that is used to refer to them.

Identifiers must contain at least one character other than white space and must not contain the comma (`,`), semicolon (`;`) or plus sign (`+`) characters, as these are used to separate items in lists. They are not case or "white space" sensitive. For example, "`CNC1`", "`cnc1`" and "`CNC 1`" will all be treated as identifying the same entity because they differ only in case or in the amount of white space they contain.

Even though they may be composed of digits, identifiers are not numeric. For example, "`1`" and "`001`" are distinct identifiers.

Each kind of entity has its own set of identifiers, so (for example) an order and a resource may have the same identifier. The exceptions are:

- resources and resource groups share a single set of identifiers, so a group may not have the same identifier as a resource;
- operation identifiers need only be unique within their routing;
- `OFF` is reserved and may not be used as a shift identifier.

All references to an entity in the input and output are made using its identifier.

2.4 Lists

Some values are lists of identifiers, for example the skills held by a member of staff. List items are separated by commas. White space around the items is ignored, so "`WELDER, FITTER`" and "`WELDER,FITTER`" are the same list.

2.5 Dates, Times and Durations

The PPS uses the following kinds of time value. All times are local times at the production site; the PPS does not adjust for daylight saving.

- A *date* is a calendar date, for example `2027-01-04`.
- A *date-time* is a date together with a time of day, for example `2027-01-04 07:30`. The PPS works to a resolution of one minute; seconds are ignored.

  When a date is given where a date-time is expected, it is interpreted as follows:

  - for values that mark the *start* of a period (for example the release date of an order) the time is the start of the day, `00:00`;
  - for values that mark the *end* of a period (the due date of an order, the end date of the horizon and the latest finish of maintenance) the time is the end of the day, i.e. `00:00` on the following day.

  So an order that is due on `2027-01-08` is on time if it is completed at any time on that day.
- A *day time* is a time of day on the 24-hour clock, for example `15:30`. Day times are used to define shifts.
- A *duration* is an elapsed period of time in hours and minutes, for example `2:30`. Durations may exceed 24 hours.

2.6 Planning Horizon

The *planning horizon* is the period of time covered by a scenario. It runs from the start of the start date to the end of the end date. All operations and maintenance must be scheduled within the horizon. An order that cannot be completed within the horizon is reported as unscheduled.

When rescheduling, the current time lies within the horizon and no new work is started before it.

2.7 Resources

A *resource* is anything that performs operations and has limited capacity: a machine, a work centre, a bay, a production line, an oven, a test bench or an outside supplier.

Each resource has a capacity: the number of operations that it can process at the same time. A resource with a capacity of n behaves like n identical *units*, each of which processes one operation at a time. For example, a welding bay with two booths can be modelled as a single resource with a capacity of two. An operation that needs more than one unit (for example, a large item that occupies two booths) can say so with the Resource Units column.

Resources that can do the same work can be placed in a *resource group*. An operation that requires a group may be carried out on any *one* of the resources in the group, and the PPS chooses which. For example, if `CNC1` and `CNC2` are both in the group `CNC`, then a milling operation that requires `CNC` may be carried out on either machine.

A resource is available at all times within the horizon unless it has a calendar, in which case it is available only during the shifts of that calendar. In either case, a resource is not available during its shutdowns and maintenance.

2.8 Shifts, Shift Patterns and Calendars

Working time is described using shifts and shift patterns.

A *shift* is a period of working time within a day, defined by a start and a finish day time. If the finish time is at or before the start time, the shift finishes on the following day; for example a shift from `22:00` to `06:00` is a night shift.

A *shift pattern* is a repeating cycle of days. For each day of the cycle it lists the shifts worked on that day, separated by plus signs (`+`); `OFF` (or nothing) means that the day is not worked. The days are separated by commas. For example, the pattern

```
DAY+EVE, DAY+EVE, DAY+EVE, DAY+EVE, DAY+EVE, OFF, OFF
```

is a seven-day cycle in which the `DAY` and `EVE` shifts are worked on the first five days and nothing is worked on the last two. Each pattern has a pattern start date on which the first day of the cycle falls. The cycle may be of any length; for example a 14-day cycle can describe a fortnightly roster.

Shift patterns are used as the *calendar* of a resource and as the roster of a member of staff. Overlapping or adjacent shifts on the same day are merged.

2.9 Routings and Operations

A *routing* (also called a recipe, process plan or bill of operations) describes how a kind of product is made. It is a set of *operations*, each of which is a step that is carried out on a resource. Every order follows exactly one routing.

For each operation the routing specifies:

- the resource or resource group on which it is carried out;
- its duration, as a fixed time plus an optional time per unit of the order's quantity. For example, an operation with a duration of `1:00` and a duration per unit of `0:05` takes 1 hour 50 minutes for an order of 10 units. An operation whose total duration is zero is not needed and is skipped.
- optionally, the number of staff and the skill they need;
- optionally, a set-up time;
- whether it is interruptible.

An *interruptible* operation may be paused when its resource or staff stop working (at the end of a shift, for a shutdown, and so on) and resumed when they start working again. A *non-interruptible* operation must be carried out in one continuous period of working time; for example, a paint job that cannot be left half finished overnight. Operations are interruptible unless stated otherwise. The duration of an operation is its working time; the elapsed time between its start and finish includes any interruptions.

2.10 Precedences and Delays

A *precedence* between two operations of a routing states that one operation (the *before* operation) must finish before the other (the *after* operation) can start.

If a routing has no precedences, its operations are carried out one after the other, in the order in which they are listed in the Operations sheet. If a routing has precedences, then they *replace* that default order and only the given precedences apply. This allows operations to be carried out in parallel; for example, the parts of a cabinet may be milled and welded at the same time if both operations need only wait for cutting to finish. The precedences of a routing must not form a cycle.

A precedence can also specify:

- a *minimum delay*: the after operation cannot start until at least this much time has elapsed since the before operation finished. Delays are elapsed (calendar) time, not working time, and are used for processes that take time but do not need a resource, such as curing, drying, cooling or outsourced work.
- a *maximum delay*: the after operation must start no more than this much time after the before operation finishes. For example, welded parts may need to be painted within a day to stop them from rusting.
- a *progress threshold*: instead of waiting for the before operation to finish, the after operation may start once the before operation is at least this percentage complete. This allows overlapping operations, for example starting to mill the first parts of a batch while the rest are still being cut. The after operation is also prevented from finishing before the before operation. A precedence with a progress threshold cannot also have a minimum delay.

2.11 Orders

An *order* (also called a job, works order or production order) is a quantity of a product to be made. Each order follows a single routing, and the order is complete when all of the operations of its routing are complete. Orders may also represent one-off jobs such as rework or prototypes, with a routing of their own.

Each order has:

- a *release date*: work on the order cannot start before this time, for example because materials will not arrive until then;
- a *due date*: the time by which the order should be complete. Due dates are not hard constraints: if an order cannot be completed by its due date it is scheduled late, and its *lateness* is the time by which it is late;
- a *priority* from 1 (most important) to 10 (least important) that determines which orders are scheduled first, or are made late, when there is not enough capacity for all of them;
- a *quantity*, which scales the per-unit duration of each operation;
- optionally, a *family*, used to calculate changeover times;
- optionally, a *probability*: the likelihood that a potential order (such as a quote) becomes a firm order. Probabilities are used only in planning.

An order is either scheduled in full or not at all.

2.12 Order Operations

The operations of an order are those of its routing, but some of their details can be changed for an individual order. An *order operation* can:

- require a particular resource (or a different group) instead of that given by the routing;
- give the duration and staffing of the operation for this order, instead of calculating them from the routing;
- skip the operation for this order, by giving a duration of zero;
- give a time before which the operation cannot start, for example because a component or a drawing will not be ready until then;
- give the status and progress of the operation, or fix its start time.

2.13 Order Precedences

An *order precedence* links two different orders. By default it states that the *after* order cannot start until the *before* order is complete. Either side may instead name a particular operation: for example, the assembly operation of one order may need to wait for the order that makes its sub-assemblies. An order precedence may also have a minimum delay.

If the before order cannot be scheduled, then neither can the after order. The order precedences must not form a cycle.

2.14 Staff and Skills

Staff are the people who carry out operations. Each member of staff has a set of *skills* (for example `WELDER` or `INSPECTOR`) and works according to a shift pattern. They are not available during their *absences* (leave, training and so on).

An operation may require a number of staff, all of whom must have a given skill. The PPS assigns individual staff to the operation, and the same staff work on it from start to finish. A member of staff works on at most one operation at a time. An operation is only worked on while its resource *and* all of its staff are working; an interruptible operation pauses when any of them stops.

If a scenario does not contain any staff, then staff requirements are ignored and labour is assumed to be unlimited.

2.15 Set-up Times and Changeovers

A *set-up* is preparation of a resource before an operation, such as loading a program and fixtures on a machine. Set-up occupies the resource (and the operation's staff) immediately before the operation starts.

The set-up time of an operation is the sum of:

- its setup time, which applies every time the operation is carried out; and
- the *changeover time* from the family of the previous operation carried out on the same resource unit to the family of this one, if they differ.

Changeover times are *sequence dependent*: for example, changing a paint booth from black to white may take much longer than changing it from white to black. The PPS sequences operations to reduce the total time spent on set-ups.

2.16 Shutdowns

A *shutdown* is a fixed period of time during which a resource cannot be used, for example for a planned repair. A shutdown that does not name a resource applies to every resource on the site, for example a public holiday or a site-wide safety day.

Interruptible operations pause during shutdowns; non-interruptible operations cannot overlap them.

2.17 Maintenance

Maintenance is work that must be carried out on a resource some time within a window, for example preventive maintenance that must be done during a given week. Unlike a shutdown, the PPS chooses when to carry out maintenance, so that it disrupts production as little as possible. Maintenance occupies the whole of its resource (all units) and may require staff. It is never interrupted, and it must be scheduled: if there is no way to fit it in, the scenario is infeasible and an issue is reported.

2.18 Rescheduling

Production rarely goes exactly to plan. The PPS can *reschedule*: build a new schedule part-way through the horizon that takes account of the work already done.

A scenario for rescheduling gives the current time and the status of the operations that have started. Each operation has one of the following statuses:

- `NOT_STARTED`: the operation has not started. This is the default. It is scheduled at or after the current time.
- `IN_PROGRESS`: the operation has started and continues from the current time on its current resource. Its remaining duration is reduced according to its progress.
- `COMPLETE`: the operation is finished. It is not scheduled again and its precedences are treated as satisfied.
- `ON_HOLD`: the operation cannot be carried out at present, for example because it is waiting on a design change or a quality problem. It is not scheduled, nor are any of the operations that must follow it. Operations of the order that do not depend on it may still be scheduled.

An operation may also be given a fixed start, for example because it has been promised to a customer who wishes to witness it. The PPS must start it at exactly that time.

2.19 Capacity Planning

In planning mode, the horizon is divided into consecutive *time buckets* of a fixed number of days, starting on the start date. (The last bucket may be shorter.) Each operation is assigned to a single time bucket and a single resource, and detailed timing within the bucket is not considered.

Each operation has a work content: the number of hours of capacity it consumes. This defaults to its duration in hours multiplied by the number of staff it needs (or by one if it needs no staff), so capacities are effectively given in labour hours for staffed operations and machine hours otherwise.

Each resource has two capacities, in hours, for each day of the horizon:

- a *hard capacity*, which is never exceeded;
- a *soft capacity*, which should not be exceeded but may be at a cost (for example by working overtime).

The capacity of a resource in a bucket is the sum of its capacities on the days of the bucket. A resource's daily capacities are its default capacities on each working day of its calendar (or on every day, if it has no calendar) and zero on other days, unless they are overridden for particular dates in the Capacities sheet.

Precedences are approximated in planning mode: the after operation must be in the same bucket as the before operation or a later one. A minimum delay of d days means that the after operation's bucket must be at least d divided by the bucket size (rounded down) buckets after the before operation's. For example, with weekly buckets a delay of 2 days allows both operations to be in the same week, but a delay of 7 days requires the after operation to be in the following week or later. Maximum delays and progress thresholds are ignored.

An order's probability is used to select the orders to plan: orders whose probability is below the probability threshold are left out. By running a scenario with different thresholds, a planner can see the load under optimistic and pessimistic assumptions about which quotes will be won.

Staff, absences, set-up times, changeovers, shutdowns, maintenance and fixed starts are ignored in planning mode; use the Capacities sheet to reduce capacity on particular days instead.

2.20 Objectives

The PPS must satisfy all of the following constraints: resource capacities and calendars; precedences and delays; release dates and availability times; staff skills, rosters and absences; shutdowns; maintenance windows; fixed starts; and the planning horizon (and, in planning mode, hard capacities). Within those constraints it optimises the following objectives, in order of importance:

1. Schedule as many orders as possible, preferring orders of higher priority.
2. Minimise the total lateness of orders, weighted by priority. (An order with priority 1 has a weight of 10, priority 2 a weight of 9, and so on, down to a weight of 1 for priority 10.)
3. In scheduling mode, minimise the total time spent on set-ups and changeovers. In planning mode, minimise the total load in excess of soft capacity.
4. In scheduling mode, complete orders as early as possible. In planning mode, balance the load across time buckets.

The PPS searches for a good solution until it reaches its time limit, and returns the best solution it has found.

3 Microsoft Excel Conventions

This section describes how the values described in Section 2 are represented in Excel.

3.1 Identifiers in Excel

Identifiers may be given as either text or numeric data. Identifiers in text cells are taken as-is, subject only to the rules concerning case and white space. Identifiers in numeric cells are only accepted if they are integers (that is, their fractional part is zero). Formulas that evaluate to text or to integers may also be used.

3.2 Lists in Excel

Lists are given as text, with items separated by commas, for example `WELDER, FITTER`. A list with a single item may also be given as a number, subject to the rules for identifiers.

3.3 Dates and Date-Times in Excel

In Excel, dates and date-times are stored as numbers: the integer part counts days and the fractional part is the time of day. Dates and date-times may be given to the PPS in any of the Excel date and time formats, for example `dd/mm/yyyy` or `dd/mm/yyyy hh:mm`. A cell containing only a date (that is, a whole number) is a date without a time, and is interpreted as described in Section 2.5. Text that looks like a date (for example `"4/1/2027"` entered into a cell formatted as text) is *not* accepted, as its meaning depends on the locale.

3.4 Day Times in Excel

Day times are given as Excel times, i.e. numbers from `0` (`00:00`) up to but not including `1` (`24:00`), in any Excel time format such as `hh:mm`. The date part, if any, is ignored.

3.5 Durations in Excel

Durations are given as Excel times, where `1` is 24 hours. For example, `0.5` is 12 hours and `1.5` is 36 hours. Durations of 24 hours or more should be displayed with Excel's elapsed time format `[h]:mm`; with the format `hh:mm`, Excel would display 36 hours as `12:00`, although the value stored (and used by the PPS) is still 36 hours.

Value	hh:mm	[h]:mm	Duration
`0.0625`	01:30	1:30	1 hour 30 minutes
`0.5`	12:00	12:00	12 hours
`1.5`	12:00	36:00	36 hours

Table 1: Durations in Excel.

3.6 Numbers, Percentages and Yes/No Values in Excel

Numbers are given in numeric cells. Where a column requires an integer, the fractional part of the value must be zero.

Percentages are numbers from `0` to `100`. If the cell has one of Excel's percentage formats, the displayed value is used; so a cell displaying `25%` and a cell containing the number `25` both mean 25 percent.

Yes/no values are given as the text `Yes` or `No` (in any case), or as the Excel Boolean values `TRUE` and `FALSE`.

3.7 Enumerations in Excel

Columns that take one of a fixed set of values, such as the status of an operation, are given as text. They are not case or white space sensitive, and underscores may be replaced by spaces; for example `IN_PROGRESS`, `in progress` and `In Progress` are all accepted.

4 Microsoft Excel Input

This section describes the Microsoft Excel input format for the PPS.

The input must be an Office Open XML workbook (`.xlsx`) or macro-enabled workbook (`.xlsm`). Office Open XML binary workbooks (`.xlsb`) and workbooks in the old Excel binary format (`.xls`) are *not* supported.

The workbook should contain the sheets listed in Table 2 and described in the following sections. Sheets that are marked as required must be present. Sheet names are not case or white space sensitive.

The workbook may contain sheets other than those recognised by the PPS. Such extra sheets are ignored. Unless otherwise noted, sheets may contain columns other than those described here. Extra columns are ignored, with the exception of extra columns in the Orders sheet, which are copied to the Orders sheet of the output. Columns may appear in any order.

The first row of each sheet contains the column headings, and each following row describes one item. Column headings are not case or white space sensitive. Empty rows are ignored. An empty cell in an optional column takes the column's default value.

The PPS evaluates any formulas in the workbook when it is loaded. Formulas must *not* refer to other workbooks. Not all Excel functions are supported; the unsupported functions are listed in Appendix B.

Sheet	Required	Contents
Configuration	Yes	Scenario parameters, including the planning horizon.
Resources	Yes	Resources, their groups, capacities and calendars.
Operations	Yes	The operations of each routing.
Routing Precedences	No	Precedences and delays between the operations of a routing.
Orders	Yes	The orders to be planned or scheduled.
Order Operations	No	Order-specific operation data, status and progress.
Order Precedences	No	Precedences between orders.
Shifts	No	Shift start and finish times.
Shift Patterns	No	Repeating cycles of shifts.
Staff	No	Staff, their skills and shift patterns.
Staff Absences	No	Periods when staff are unavailable.
Changeovers	No	Sequence-dependent changeover times.
Shutdowns	No	Periods when resources are unavailable.
Maintenance	No	Maintenance to be scheduled within a window.
Capacities	No	Daily capacity overrides for planning.

Table 2: Input sheets.

4.1 Sheet: Configuration

This sheet contains the parameters of the scenario. Each row gives the value of one parameter.

This sheet is required.

4.1.1 Column: Parameter

Required: Yes.
Type: Text.
Description: The name of a parameter; one of those described below. Parameter names are not case or white space sensitive. Each parameter may appear at most once.

4.1.2 Column: Value

Required: Yes.
Type: Depends on the parameter.
Description: The value of the parameter.

4.1.3 Parameter: Name

Required: No.
Type: Text.
Description: The name of the scenario. It is copied to the output.

4.1.4 Parameter: Mode

Required: No.
Type: Text: either `SCHEDULE` or `PLAN`.
Default: `SCHEDULE`.
Description: Whether to build a detailed schedule or a capacity plan.

4.1.5 Parameter: Start Date

Required: Yes.
Type: Excel date.
Description: The first day of the planning horizon.

4.1.6 Parameter: End Date

Required: Yes.
Type: Excel date.
Description: The last day of the planning horizon. Must not be before the start date.

4.1.7 Parameter: Current Time

Required: No; required if any operation is `IN_PROGRESS`.
Type: Excel date-time.
Description: The time at which the scenario is being rescheduled. No operation or maintenance is started before this time, other than operations that are already in progress. Must be within the planning horizon.
Default: The start of the planning horizon.

4.1.8 Parameter: Time Limit

Required: No.
Type: Number (positive integer).
Default: `60`.
Description: The maximum time, in seconds, that the PPS spends searching for a solution.

4.1.9 Parameter: Time Bucket Size

Required: No.
Type: Number (positive integer).
Default: `7`.
Description: The number of days in each time bucket. Only used in planning mode.

4.1.10 Parameter: Probability Threshold

Required: No.
Type: Number from `0` to `1`.
Default: `0` (plan all orders).
Description: Only orders whose probability is greater than or equal to this value are planned. Only used in planning mode.

4.2 Sheet: Resources

This sheet defines the resources.

This sheet is required and must contain at least one resource.

4.2.1 Column: Id

Required: Yes.
Type: Identifier.
Description: A unique identifier for the resource.

4.2.2 Column: Description

Required: No.
Type: Text.
Description: A description of the resource, for the user's reference.

4.2.3 Column: Group

Required: No.
Type: Identifier.
Default: The resource is not in a group.
Description: The identifier of the resource group that the resource belongs to. Groups are defined implicitly by this column. A group identifier must not be the same as the identifier of a resource. All of the resources in a group should be able to carry out the same operations.

4.2.4 Column: Capacity

Required: No.
Type: Number (positive integer).
Default: `1`.
Description: The number of operations that the resource can process at the same time; that is, its number of identical units.

4.2.5 Column: Calendar

Required: No.
Type: Identifier.
Default: The resource is available at all times.
Description: The identifier of a shift pattern in the Shift Patterns sheet that defines when the resource is working.

4.2.6 Column: Default Hard Capacity

Required: In planning mode, yes, unless every day of the horizon is given in the Capacities sheet; otherwise no.
Type: Number (non-negative).
Description: The hard capacity, in hours, of the resource on each working day. Only used in planning mode.

4.2.7 Column: Default Soft Capacity

Required: No.
Type: Number (non-negative).
Default: The default hard capacity.
Description: The soft capacity, in hours, of the resource on each working day. Must not be greater than the default hard capacity. Only used in planning mode.

4.3 Sheet: Operations

This sheet defines the routings. Each row defines one operation of a routing; a routing is the set of rows with the same Routing identifier. If the routing has no routing precedences, its operations are carried out in the order of the rows.

This sheet is required.

4.3.1 Column: Routing

Required: Yes.
Type: Identifier.
Description: The identifier of the routing that this operation belongs to.

4.3.2 Column: Operation

Required: Yes.
Type: Identifier.
Description: An identifier for the operation that is unique within its routing.

4.3.3 Column: Resource

Required: Yes.
Type: Identifier.
Description: The identifier of the resource, or resource group, on which the operation is carried out. If a group is given, the operation is carried out on any one of the resources in the group.

4.3.4 Column: Duration

Required: No.
Type: Excel duration.
Default: `0:00`.
Description: The fixed part of the duration of the operation, which does not depend on the order quantity.

4.3.5 Column: Duration Per Unit

Required: No.
Type: Excel duration.
Default: `0:00`.
Description: The duration of the operation for each unit of the order's quantity. The total duration of the operation for an order is Duration plus Quantity times Duration Per Unit. If the total is zero, the operation is skipped.

4.3.6 Column: Setup Time

Required: No.
Type: Excel duration.
Default: `0:00`.
Description: The set-up time needed on the resource immediately before the operation. Ignored in planning mode.

4.3.7 Column: Resource Units

Required: No.
Type: Number (positive integer).
Default: `1`.
Description: The number of units of the resource that the operation occupies. Must not be greater than the resource's capacity (or, for a group, the capacity of each resource in the group).

4.3.8 Column: Staff

Required: No.
Type: Number (non-negative integer).
Default: `0`.
Description: The number of staff needed to carry out the operation.

4.3.9 Column: Skill

Required: If Staff is greater than zero and the scenario has a Staff sheet.
Type: Identifier.
Description: The skill that each of the operation's staff must have.

4.3.10 Column: Work Content

Required: No.
Type: Number (non-negative).
Default: The total duration in hours, multiplied by the number of staff (or by one if the operation needs no staff).
Description: The number of hours of capacity that the operation consumes, for one order. Only used in planning mode.

4.3.11 Column: Interruptible

Required: No.
Type: Yes/no.
Default: `Yes`.
Description: Whether the operation may be interrupted by breaks in working time.

4.3.12 Column: Description

Required: No.
Type: Text.
Description: A description of the operation, for the user's reference.

4.4 Sheet: Routing Precedences

This sheet defines precedences between the operations of a routing. Each row defines one precedence. For a routing that has any rows in this sheet, *all* of its precedences must be given here; the default, sequential order of its operations no longer applies.

This sheet is not required.

4.4.1 Column: Routing

Required: Yes.
Type: Identifier.
Description: The identifier of a routing in the Operations sheet.

4.4.2 Column: Before

Required: Yes.
Type: Identifier.
Description: The identifier of the operation of the routing that must be done first.

4.4.3 Column: After

Required: Yes.
Type: Identifier.
Description: The identifier of the operation of the routing that must be done second. Must be different from Before.

4.4.4 Column: Minimum Delay

Required: No.
Type: Excel duration.
Default: `0:00`.
Description: The minimum elapsed time between the finish of the before operation and the start of the after operation.

4.4.5 Column: Maximum Delay

Required: No.
Type: Excel duration.
Default: No maximum.
Description: The maximum elapsed time between the finish of the before operation and the start of the after operation. Must not be less than the minimum delay. Ignored in planning mode.

4.4.6 Column: Progress Threshold

Required: No.
Type: Percentage.
Default: `100` (the before operation must finish).
Description: The after operation may start once the before operation is this percentage complete. Must not be given together with a minimum delay. Ignored in planning mode.

4.5 Sheet: Orders

This sheet defines the orders.

Columns other than those described below are copied, as they are, to the Orders sheet of the output. They can be used to carry information such as customer names or reference numbers through the PPS.

This sheet is required.

4.5.1 Column: Id

Required: Yes.
Type: Identifier.
Description: A unique identifier for the order.

4.5.2 Column: Routing

Required: Yes.
Type: Identifier.
Description: The identifier of the routing, from the Operations sheet, that the order follows.

4.5.3 Column: Quantity

Required: No.
Type: Number (non-negative).
Default: `1`.
Description: The quantity to be made, in whatever units the routing's per-unit durations are given in.

4.5.4 Column: Release Date

Required: No.
Type: Excel date or date-time.
Default: The start of the planning horizon.
Description: The time before which no work on the order can start.

4.5.5 Column: Due Date

Required: Yes.
Type: Excel date or date-time.
Description: The time by which the order should be complete. If a date without a time is given, the order is due at the end of that day. Must be after the release date.

4.5.6 Column: Priority

Required: No.
Type: Number (integer from 1 to 10).
Default: `5`.
Description: The priority of the order, where 1 is the most important.

4.5.7 Column: Probability

Required: No.
Type: Number from `0` to `1`.
Default: `1`.
Description: The probability that the order will go ahead. Firm orders have a probability of `1`. Only used in planning mode; see the Probability Threshold parameter.

4.5.8 Column: Family

Required: No.
Type: Identifier.
Default: No family.

Description: The family of the order (for example its colour or material), used to look up changeover times. No changeover time applies before or after an operation of an order without a family.

4.6 Sheet: Order Operations

This sheet gives order-specific data for some of the operations of some orders, including the status and progress of work already under way. Each row describes one operation of one order; an operation of an order may appear in at most one row. Operations that do not appear in this sheet are as defined by the order's routing, and have not started.

This sheet is not required.

4.6.1 Column: Order

Required: Yes.
Type: Identifier.
Description: The identifier of an order in the Orders sheet.

4.6.2 Column: Operation

Required: Yes.
Type: Identifier.
Description: The identifier of an operation of the order's routing.

4.6.3 Column: Resource

Required: If the status is `IN_PROGRESS` and the routing gives a resource group; otherwise no.
Type: Identifier.
Default: The resource or group given by the routing.
Description: The resource or resource group on which the operation must be carried out for this order. For an operation that is in progress, this is the resource on which it is being carried out.

4.6.4 Column: Duration

Required: No.
Type: Excel duration.
Default: The total duration calculated from the routing.
Description: The total duration of the operation for this order. A duration of zero skips the operation.

4.6.5 Column: Staff

Required: No.
Type: Number (non-negative integer).
Default: The number of staff given by the routing.
Description: The number of staff needed for the operation for this order.

4.6.6 Column: Available From

Required: No.
Type: Excel date or date-time.
Default: The order's release date.
Description: The time before which the operation cannot start, for example because materials or components will not be available until then.

4.6.7 Column: Status

Required: No.
Type: Text: one of `NOT_STARTED`, `IN_PROGRESS`, `COMPLETE` or `ON_HOLD`.
Default: `NOT_STARTED`.
Description: The status of the operation.

4.6.8 Column: Progress

Required: No.
Type: Percentage.

Default: `0`.
Description: For an operation that is `IN_PROGRESS`, the percentage of the operation's duration that has been completed. The operation's remaining duration is reduced accordingly; for example, an operation of 10 hours that is 40% complete has 6 hours remaining. Ignored for other statuses.

4.6.9 Column: Fixed Start

Required: No.
Type: Excel date-time.
Default: The PPS chooses the start time.
Description: The time at which the operation must start. Must not be before the current time. Only allowed for operations that are `NOT_STARTED`. Ignored in planning mode.

4.7 Sheet: Order Precedences

This sheet defines precedences between orders. Each row defines one precedence.

This sheet is not required.

4.7.1 Column: Before

Required: Yes.
Type: Identifier.
Description: The identifier of the order that must be done first.

4.7.2 Column: Before Operation

Required: No.
Type: Identifier.
Default: The whole of the before order must be complete.
Description: An operation of the before order that must be complete.

4.7.3 Column: After

Required: Yes.
Type: Identifier.
Description: The identifier of the order that must be done second. Must be different from Before.

4.7.4 Column: After Operation

Required: No.
Type: Identifier.
Default: No operation of the after order may start.
Description: An operation of the after order that must wait.

4.7.5 Column: Minimum Delay

Required: No.
Type: Excel duration.
Default: `0:00`.
Description: The minimum elapsed time between the completion of the before order (or operation) and the start of the after order (or operation).

4.8 Sheet: Shifts

This sheet defines shifts.

This sheet is required if the scenario has a Shift Patterns sheet.

4.8.1 Column: Id

Required: Yes.
Type: Identifier.
Description: A unique identifier for the shift. Must not be `OFF`.

4.8.2 Column: Start Time

Required: Yes.
Type: Excel day time.
Description: The time at which the shift starts.

4.8.3 Column: Finish Time

Required: Yes.
Type: Excel day time.
Description: The time at which the shift finishes. If it is at or before the start time, the shift finishes on the following day. For example, a shift that finishes at midnight has a finish time of `00:00`.

4.9 Sheet: Shift Patterns

This sheet defines shift patterns, which are used as resource calendars and staff rosters.

This sheet is required if any resource has a calendar or the scenario has a Staff sheet.

4.9.1 Column: Id

Required: Yes.
Type: Identifier.
Description: A unique identifier for the shift pattern.

4.9.2 Column: Pattern Start

Required: No.
Type: Excel date.
Default: The start date of the horizon.
Description: A date on which the first day of the pattern falls. It may be before the start of the horizon; the pattern repeats in both directions.

4.9.3 Column: Shifts

Required: Yes.
Type: Text.
Description: The days of the pattern, separated by commas. Each day is either `OFF`, empty, or one or more shift identifiers from the Shifts sheet separated by plus signs. For example, `DAY, DAY, DAY, DAY, DAY, OFF, OFF` is a five-day week starting on the pattern start date.

4.10 Sheet: Staff

This sheet defines the staff. If it is not present, staff requirements are ignored.

This sheet is not required.

4.10.1 Column: Id

Required: Yes.
Type: Identifier.
Description: A unique identifier for the member of staff.

4.10.2 Column: Name

Required: No.
Type: Text.
Description: The name of the member of staff, for the user's reference.

4.10.3 Column: Skills

Required: Yes.
Type: List of identifiers.
Description: The skills held by the member of staff. Skills are defined implicitly by this column.

4.10.4 Column: Shift Pattern

Required: Yes.
Type: Identifier.
Description: The identifier of the shift pattern, from the Shift Patterns sheet, that the member of staff works.

4.11 Sheet: Staff Absences

This sheet defines periods during which staff are not available, such as leave or training. Each row describes one period of absence for one member of staff.

This sheet is not required.

4.11.1 Column: Staff

Required: Yes.
Type: Identifier.
Description: The identifier of a member of staff in the Staff sheet.

4.11.2 Column: Start Time

Required: Yes.
Type: Excel date or date-time.
Description: The start of the absence.

4.11.3 Column: Finish Time

Required: Yes.
Type: Excel date or date-time.
Description: The end of the absence. Must be after the start time. Note that a date without a time is the *start* of that day: an absence from `11/01/2027` to `13/01/2027` covers 11 and 12 January.

4.11.4 Column: Reason

Required: No.
Type: Text.
Description: The reason for the absence, for the user's reference.

4.12 Sheet: Changeovers

This sheet defines sequence-dependent changeover times between order families. Each row gives the changeover time on a resource from one family to another. If no row applies, the changeover time is zero.

This sheet is not required.

4.12.1 Column: Resource

Required: No.
Type: Identifier.
Default: All resources.
Description: The resource, or resource group, to which the changeover time applies. A row for a resource takes precedence over a row for its group, which takes precedence over a row without a resource.

4.12.2 Column: From Family

Required: Yes.
Type: Identifier.
Description: The family of the previous operation on the resource unit.

4.12.3 Column: To Family

Required: Yes.
Type: Identifier.
Description: The family of the next operation on the resource unit. Must be different from the from family.

4.12.4 Column: Time

Required: Yes.
Type: Excel duration.
Description: The changeover time.

4.13 Sheet: Shutdowns

This sheet defines shutdowns. Each row describes one shutdown.

This sheet is not required.

4.13.1 Column: Resource

Required: No.
Type: Identifier.
Default: All resources (a site-wide shutdown).
Description: The resource, or resource group, that is shut down. A shutdown of a group applies to every resource in the group.

4.13.2 Column: Start Time

Required: Yes.
Type: Excel date or date-time.
Description: The start of the shutdown.

4.13.3 Column: Finish Time

Required: Yes.
Type: Excel date or date-time.
Description: The end of the shutdown. Must be after the start time. As for absences, a date without a time is the start of that day.

4.13.4 Column: Reason

Required: No.
Type: Text.
Description: The reason for the shutdown, for the user's reference.

4.14 Sheet: Maintenance

This sheet defines maintenance to be scheduled. Each row describes one maintenance activity.

This sheet is not required.

4.14.1 Column: Id

Required: Yes.
Type: Identifier.
Description: A unique identifier for the maintenance.

4.14.2 Column: Resource

Required: Yes.
Type: Identifier.
Description: The resource to be maintained. Must be a resource, not a group.

4.14.3 Column: Duration

Required: Yes.
Type: Excel duration.
Description: The duration of the maintenance. It is carried out in one continuous period of the resource's working time.

4.14.4 Column: Earliest Start

Required: No.
Type: Excel date or date-time.
Default: The start of the planning horizon.
Description: The earliest time at which the maintenance may start.

4.14.5 Column: Latest Finish

Required: No.
Type: Excel date or date-time.
Default: The end of the planning horizon.
Description: The time by which the maintenance must be finished. If a date without a time is given, it is the end of that day.

4.14.6 Column: Staff

Required: No.
Type: Number (non-negative integer).
Default: `0`.
Description: The number of staff needed to carry out the maintenance.

4.14.7 Column: Skill

Required: If Staff is greater than zero and the scenario has a Staff sheet.
Type: Identifier.
Description: The skill that each of the maintenance staff must have.

4.15 Sheet: Capacities

This sheet overrides the default capacities of resources on particular days, for capacity planning. Each row gives the capacities of one resource on one day. For example, a row with a hard capacity of zero can be used for a public holiday or a planned shutdown.

This sheet is not required, and is ignored in scheduling mode.

4.15.1 Column: Resource

Required: Yes.
Type: Identifier.
Description: The identifier of a resource in the Resources sheet.

4.15.2 Column: Date

Required: Yes.
Type: Excel date.
Description: The day to which the capacities apply. Each resource and date may appear at most once.

4.15.3 Column: Hard Capacity

Required: Yes.
Type: Number (non-negative).
Description: The hard capacity, in hours, of the resource on that day.

4.15.4 Column: Soft Capacity

Required: No.
Type: Number (non-negative).
Default: The hard capacity.
Description: The soft capacity, in hours, of the resource on that day. Must not be greater than the hard capacity.

5 Microsoft Excel Output

This section describes the Microsoft Excel output format of the PPS. The output is an Office Open XML workbook (`.xlsx`). It refers to the entities of the scenario (orders, resources, staff and so on) by their identifiers.

In scheduling mode, the output contains the following sheets: Summary, Schedule, Orders, Resource Utilisation, Staff Schedule (if the scenario has staff) and Issues.

In planning mode, it contains the following sheets: Summary, Plan, Orders, Capacity Plan and Issues.

If the scenario is not valid (for example, a required sheet is missing or an order refers to a routing that does not exist), no solution is produced and the output contains only the Issues sheet, which lists the problems found.

5.1 Sheet: Summary

This sheet contains a summary of the solution. It has two columns, **Measure** and **Value**, and the following rows.

5.1.1 Name

Type: Text.
Description: The name of the scenario.

5.1.2 Orders

Type: Number.
Description: The number of orders in the scenario. In planning mode, orders below the probability threshold are not counted.

5.1.3 Scheduled Orders

Type: Number.
Description: The number of orders that were scheduled (or planned).

5.1.4 On Time Orders

Type: Number.
Description: The number of scheduled orders that are completed by their due dates.

5.1.5 Late Orders

Type: Number.
Description: The number of scheduled orders that are completed after their due dates.

5.1.6 Unscheduled Orders

Type: Number.
Description: The number of orders that could not be scheduled, or are on hold.

5.1.7 Total Lateness

Type: Excel duration.
Description: The total lateness of the late orders.

5.1.8 Schedule Start

Type: Excel date-time.
Description: The start of the first scheduled operation.

5.1.9 Schedule Finish

Type: Excel date-time.
Description: The finish of the last scheduled operation.

5.2 Sheet: Schedule

This sheet is produced in scheduling mode. Each row describes one scheduled operation or maintenance activity. Rows are ordered by start time. Operations that are `COMPLETE`, `ON_HOLD` or skipped do not appear.

5.2.1 Type

Type: Text: either `OPERATION` or `MAINTENANCE`.
Description: Whether the row describes an operation of an order or maintenance.

5.2.2 Order

Type: Identifier.
Description: The identifier of the order. Empty for maintenance.

5.2.3 Operation

Type: Identifier.
Description: The identifier of the operation, or of the maintenance.

5.2.4 Resource

Type: Identifier.
Description: The resource on which the operation is carried out. If the operation requires a resource group, this is the resource chosen from the group.

5.2.5 Setup Start

Type: Excel date-time.
Description: The start of the set-up (including any changeover) before the operation. The set-up ends at the start time. Empty if there is no set-up.

5.2.6 Start Time

Type: Excel date-time.
Description: The start of the operation. For an operation that is in progress, this is the current time.

5.2.7 Finish Time

Type: Excel date-time.
Description: The finish of the operation.

5.2.8 Duration

Type: Excel duration.
Description: The working time of the operation (for an operation in progress, its remaining working time). If the operation is interrupted, this is less than the time between its start and finish.

5.2.9 Staff

Type: List of identifiers.
Description: The staff assigned to the operation. Empty if the operation needs no staff or the scenario has no staff.

5.3 Sheet: Orders

This sheet describes the outcome for each order. Any extra columns of the input Orders sheet are copied to the end of each row.

5.3.1 Id

Type: Identifier.
Description: The identifier of the order.

5.3.2 Routing

Type: Identifier.
Description: The identifier of the order's routing.

5.3.3 Release Date

Type: Excel date or date-time.
Description: The order's release date, as given in the input.

5.3.4 Due Date

Type: Excel date or date-time.
Description: The order's due date, as given in the input.

5.3.5 Start Time

Type: Excel date-time.
Description: The start of the order's first operation (including set-up). In planning mode, the start of the time bucket of its first operation. Empty if the order was not scheduled.

5.3.6 Completion Time

Type: Excel date-time.
Description: The finish of the order's last operation. In planning mode, the end of the time bucket of its last operation. Empty if the order was not scheduled.

5.3.7 Lateness

Type: Excel duration.
Description: The time by which the completion time is after the due date; zero if the order is on time.

5.3.8 Status

Type: Text.
Description: One of the following:

- `ON_TIME`: the order is scheduled to complete by its due date.
- `LATE`: the order is scheduled to complete after its due date.
- `UNSCHEDULED`: the order could not be scheduled; the Issues sheet gives the reason.
- `ON_HOLD`: the order has an operation that is on hold. Operations of the order that do not depend on it may still appear in the schedule.
- `COMPLETE`: all of the order's operations are complete.
- `EXCLUDED`: in planning mode, the order's probability is below the probability threshold.

5.4 Sheet: Resource Utilisation

This sheet is produced in scheduling mode. Each row gives the utilisation of one resource on one day of the horizon.

5.4.1 Resource

Type: Identifier.
Description: The identifier of the resource.

5.4.2 Date

Type: Excel date.
Description: The day.

5.4.3 Available Time

Type: Excel duration.
Description: The working time of the resource on that day, multiplied by its capacity, less shutdowns and maintenance.

5.4.4 Busy Time

Type: Excel duration.
Description: The time spent on operations and set-ups on that day, summed over the resource's units.

5.4.5 Utilisation

Type: Number.
Description: The busy time as a percentage of the available time. Empty if the available time is zero.

5.5 Sheet: Staff Schedule

This sheet is produced in scheduling mode when the scenario has staff. Each row describes one assignment of a member of staff to an operation or to maintenance. Rows are ordered by staff and then start time.

5.5.1 Staff

Type: Identifier.
Description: The identifier of the member of staff.

5.5.2 Type

Type: Text: either `OPERATION` or `MAINTENANCE`.
Description: What the member of staff is assigned to.

5.5.3 Order

Type: Identifier.
Description: The identifier of the order. Empty for maintenance.

5.5.4 Operation

Type: Identifier.
Description: The identifier of the operation, or of the maintenance.

5.5.5 Resource

Type: Identifier.
Description: The resource on which the work is carried out.

5.5.6 Start Time

Type: Excel date-time.
Description: The start of the assignment, including set-up.

5.5.7 Finish Time

Type: Excel date-time.
Description: The finish of the assignment.

5.6 Sheet: Plan

This sheet is produced in planning mode. Each row gives the time bucket and resource of one operation of a planned order.

5.6.1 Order

Type: Identifier.
Description: The identifier of the order.

5.6.2 Operation

Type: Identifier.
Description: The identifier of the operation.

5.6.3 Resource

Type: Identifier.
Description: The resource to which the operation's work content is allocated.

5.6.4 Period Start

Type: Excel date.
Description: The first day of the time bucket.

5.6.5 Period End

Type: Excel date.
Description: The last day of the time bucket.

5.6.6 Work Content

Type: Number.
Description: The hours of capacity consumed by the operation.

5.7 Sheet: Capacity Plan

This sheet is produced in planning mode. Each row gives the load on one resource in one time bucket.

5.7.1 Resource

Type: Identifier.
Description: The identifier of the resource.

5.7.2 Period Start

Type: Excel date.
Description: The first day of the time bucket.

5.7.3 Period End

Type: Excel date.
Description: The last day of the time bucket.

5.7.4 Hard Capacity

Type: Number.
Description: The hard capacity, in hours, of the resource in the bucket.

5.7.5 Soft Capacity

Type: Number.
Description: The soft capacity, in hours, of the resource in the bucket.

5.7.6 Load

Type: Number.
Description: The total work content, in hours, of the operations allocated to the resource in the bucket.

5.7.7 Utilisation

Type: Number.
Description: The load as a percentage of the soft capacity. A value over 100 means that the soft capacity is exceeded. Empty if the soft capacity is zero.

5.8 Sheet: Issues

This sheet lists problems found in the scenario, and the reasons why orders could not be scheduled. It is always present, and is empty (apart from its headings) if there are no issues.

5.8.1 Order

Type: Identifier.
Description: The order that the issue concerns, if any.

5.8.2 Operation

Type: Identifier.
Description: The operation that the issue concerns, if any.

5.8.3 Severity

Type: Text: either `ERROR` or `WARNING`.
Description: `ERROR` means that the scenario is invalid, or that an order or maintenance activity could not be scheduled. `WARNING` means that something may not be as intended, for example a member of staff with no shifts in the horizon, but a solution was still produced.

5.8.4 Message

Type: Text.
Description: A description of the issue. Issues in the input also give the sheet, row and column concerned.

Appendices

A Example Workbooks

The following example workbooks accompany this document. The basic example describes a small fabrication shop that makes brackets, frames and cabinets with seven resources over three weeks. Each extension builds on the previous one by adding the sheets and columns for one more feature; the exception is extension 8, which is a separate capacity planning example.

Workbook	Demonstrates
`pps_template.xlsx`	Every input sheet, with headers only.
`pps_basic.xlsx`	Configuration, resources (including a group and resources with a capacity greater than one), routings with per-unit durations, and orders with an extra **Customer** column.
`pps_basic_solution.xlsx`	The output for the basic example.
`pps_extension_1.xlsx`	Routing precedences: parallel operations, minimum and maximum delays and a progress threshold.
`pps_extension_2.xlsx`	Shifts and shift patterns used as resource calendars, including two shifts a day and a shift that ends at midnight; non-interruptible operations.
`pps_extension_3.xlsx`	Staff with skills and shift patterns, staffed operations and absences.
`pps_extension_4.xlsx`	Set-up times, order families (paint colours) and changeovers.
`pps_extension_5.xlsx`	A resource shutdown, a site-wide shutdown and maintenance.
`pps_extension_6.xlsx`	Order operations (a required resource, a longer duration, a skipped operation and late materials) and order precedences.
`pps_extension_7.xlsx`	Rescheduling from a current time, with completed and in-progress operations, an operation on hold, a fixed start and a new rush order.
`pps_extension_8.xlsx`	Capacity planning over twelve weeks in weekly buckets, with probability-weighted orders, default capacities and capacity overrides for a public holiday, a refit and reduced hours.

Table 3: Example workbooks.

Each workbook has an **About** sheet describing it; the PPS ignores this sheet.

The basic solution was produced by a simple heuristic that schedules the orders one at a time in priority order. It illustrates the output format, but it is not an optimised schedule. Because the basic example does not give the resources a calendar, they are available around the clock.

B Unsupported Excel Functions

The following table lists the Excel functions that are *not* supported by the PPS.

ABSREF	DCOUNT	GAMMALN	NEGBINOMDIST	STANDARDIZE
APP.TITLE	DCOUNTA	GET.CELL	NORMDIST	STDEVA
ARGUMENT	DDB	GET.DOCUMENT	NORMINV	STDEVP
ASC	DPRODUCT	GET.WINDOW	NORMSDIST	STDEVPA
AVERAGEA	DSTDEV	GET.WORKBOOK	NORMSINV	STEP
BETADIST	DSTDEVP	GET.WORKSPACE	NUMBERSTRING	STEYX
BETAINV	DVAR	GETPIVOTDATA	PEARSON	SYD
BINOMDIST	DVARP	GOTO	PERCENTRANK	TDIST
CALL	ENABLE.TOOL	GROWTH	PERMUT	TIMEVALUE
CELL	END.IF	HARMEAN	PHONETIC	TINV
CHIDIST	ERROR	HYPGEOMDIST	PRESS.TOOL	TRIMMEAN
CHIINV	EVALUATE	INFO	PROB	TTEST
CHITEST	EXEC	ISPMT	QUARTILE	TYPE
CONFIDENCE	EXPONDIST	KURT	REGISTER.ID	USDOLLAR
CORREL	FDIST	LAST.ERROR	RELREF	VARA
COVAR	FINDB	LEFTB	REPLACEB	VARPA
CRITBINOM	FINV	LENB	RETURN	VDB
DATEDIF	FISHER	LINEST	RIGHTB	WEIBULL
DATESTRING	FISHERINV	LOGEST	RSQ	WINDOW.TITLE
DATEVALUE	FORECAST	LOGINV	SAVE.TOOLBAR	ZTEST
DAVERAGE	FTEST	LOGNORMDIST	SEARCHB	
DB	GAMMADIST	MIDB	SKEW	
DBCS	GAMMAINV	N	SLN	

Table 4: Unsupported Excel functions.