ORNL/TM-2024/3275

Integrated Biomass Supply Analysis and Logistics Model (IBSAL) 2.0

Robin Clark
Erin Webb

February 2024

OAK RIDGE National Laboratory

ORNL IS MANAGED BY UT-BATTELLE LLC FOR THE US DEPARTMENT OF ENERGY

DOCUMENT AVAILABILITY

Reports produced after January 1, 1996, are generally available free via OSTI.GOV.

Website www.osti.gov

Reports produced before January 1, 1996, may be purchased by members of the public from the following source:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone 703-605-6000 (1-800-553-6847)
TDD 703-487-4639
Fax 703-605-6900
E-mail info@ntis.gov
Website http://classic.ntis.gov/

Reports are available to US Department of Energy (DOE) employees, DOE contractors, Energy Technology Data Exchange representatives, and International Nuclear Information System representatives from the following source:

Office of Scientific and Technical Information
PO Box 62
Oak Ridge, TN 37831
Telephone 865-576-8401
Fax 865-576-5728
E-mail reports@osti.gov
Website https://www.osti.gov/

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL/TM-2024/3275

Environmental Sciences Division

INTEGRATED BIOMASS SUPPLY ANALYSIS AND LOGISTICS MODEL (IBSAL) 2.0

Robin Clark
Erin Webb

February 2024

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, TN 37831
managed by
UT-BATTELLE LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

CONTENTS

CONTENTS iii
LIST OF FIGURES v
LIST OF TABLES vii
ABBREVIATIONS ix
ACKNOWLEDGEMENTS xi
ABSTRACT 13
1. INTRODUCTION 13
2. MODEL NAVIGATION 14
3. MODEL ARCHITECTURE 16
    3.1 ITEMS 16
    3.2 SIMULATION DATABASE STRUCTURE 16
4. MODEL LOGIC 18
    4.1 BIOMASS SUPPLY SHED SETUP 18
    4.2 CREW TYPES 22
    4.3 HARVEST CREWS 23
    4.4 TRANSPORT CREWS 26
    4.5 FIELD ASSIGNMENT 27
    4.6 CREW AVAILABILITY \ SHIFTS 28
    4.7 EQUIPMENT FAILURES 29
    4.8 EQUIPMENT COST 31
    4.9 WEATHER 32
5. RUNNING THE MODEL 33
    5.1 GENERAL DISCUSSION ON RUNNING THE MODEL 33
    5.2 MANUAL MODEL RUNS 35
    5.3 SCENARIO RUNS 37
6. OUTPUT REPORTS 37
    6.1 PRIMARY OUTPUT REPORTS 37
    6.2 DEBUGGING LOGS 38
    6.3 DATA EXPORT MGR 39
7. CONCLUSION 41
8. REFERENCES 41
Appendix A. FILE SETUP A-3
Appendix B. DATABASE DOCUMENTATION B-3
Appendix C. ATTRIBUTE DOCUMENTATION C-3

LIST OF FIGURES

Figure 1. Main model worksheet and user interface of the model. 15
Figure 2. Illustration of basic indexing concepts applied throughout the model database. Most status tables contain one row per object, while the result tables contain one row per object per run. 17
Figure 3. Field grid illustration to select fields in a supply shed. Each black dot represents a potential field location, and the red circle symbolizes the maximum supply shed radius. 21
Figure 4. The *List Crew Types* table allows the user to rename crew types. 22
Figure 5. *Crew Type Data* table allows users to enable and disable crew types. 23
Figure 6. The process flow of the crews on the main model worksheet. 24
Figure 7. Illustration of a harvest crew unit with four crew equipment items processing a field. Afterward, the crew unit moves to the following field to process. 24
Figure 8. *Crew Type 1 Eqpt Parameters* table contains operational parameters related to crew type 1. 25
Figure 9. The *Crew Parameters* table contains the number of crews and the amount of equipment per crew for each crew type. 25
Figure 10. The travel time calculation for the wagons as they travel between the empty wagon queue and the harvesters. 26
Figure 11. The *Crew Type Schedule Data* table contains the shift-related parameters by crew type. 28
Figure 12. The *Crew Type Schedule Status* table displays the current shift status of each crew type. 29
Figure 13. The *Crew Type X Parameter* table contains the time between failures and the time to repair parameters for the crew type. 30
Figure 14. The *Crew Equipment Status* table contains the status of every crew equipment item. 30
Figure 15. The Equipment Failures h-block implements the failure logic. 31
Figure 16. The *Model Options* table contains the Boolean flag to control the equipment failures. 31
Figure 17. This figure illustrates portions of the *Cost Data* table and the *Crew Type 1 Eqpt Parameters* table, showcasing how the equipment in the *Cost Data* table is referenced in the *Crew Type X Eqpt Parameters* table. 32
Figure 18. The *Model Parameters* table contains the *Probability of Bad Weather Day* field, which controls the proportion of bad weather days during harvest. 33
Figure 19. Simulation Setup dialog, which shows the global time units set to days. 34
Figure 20. A screenshot of a model while running with the current simulation time is shown in the lower-left corner of the model. 35
Figure 21. ExtendSim toolbar with the Run Model button identified by an arrow on the toolbar. 36
Figure 22. Steps to open the Simulation Setup dialog from the Run menu. 36
Figure 23. *Table Export to Text* table controls which tables will be exported at the end of the run. 39
Figure 24. *Table Export to Excel* table allows users to automatically select the tables to export at the end of each run into Excel. The user can also indicate where the table is placed in the Excel workbook. 40
Figure 25. Data Export Mgr block dialog. 41

LIST OF TABLES

Table 1. Columns of buttons on the main model worksheet.....15
Table 2. List of custom blocks and h-blocks on the bottom right corner of the main model worksheet.....16
Table 3. List of classes in the model and the tables associated with the class.....18
Table 4. Example of the grid array of possible field locations including X and Y coordinates, distance to the refinery by direct distance, estimated road network, and a random number used for field selection.....21
Table 5. Primary result tables generated by the model.....37
Table 6. Log options contained in the *Model Options* table.....38
Table 7. Required files to run IBSAL 2.0.....A-3

ABBREVIATIONS

ASABE	American Society of Agricultural and Biological Engineers
DES	Discrete Event Simulation
GIS	Geographic Information System
IBSAL	Integrated Biomass Supply Analysis and Logistics Model
ORNL	Oak Ridge National Laboratory
TBF	Time between Failures
TTR	Time to Repair

ACKNOWLEDGEMENTS

This work was supported by the Center for Bioenergy Innovation, a Bioenergy Research Center funded by the U.S. Department of Energy Office of Biological and Environmental Research. It was authored in part by the Alliance for Sustainable Energy, LLC, the manager and operator of the National Renewable Energy Laboratory for the U.S. Department of Energy (DOE) under contract no. DE-AC36-08GO28308, and by Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. DOE under contract no. DE-AC05-00OR22725. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. government. The U.S. government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. government purposes. The authors appreciate the assistance of Stan Martin in posting the data doi.

ABSTRACT

The Integrated Biomass Supply Analysis and Logistics (IBSAL) 2.0 model simulates a feedstock supply shed's harvest and transport process to estimate the cost of delivered feedstock. IBSAL 2.0 represents an enhanced version of the original IBSAL model, specifically restructured to take advantage of the ExtendSim database. This overhaul not only accelerates simulation times but also simplifies the adaptation of the model for various feedstocks. The model sets up a supply shed of fields, harvests the fields using a series of sequential harvest operations with different crew types, and transports the harvested feedstock to a storage facility or refinery. The model employs stochastic variables to represent critical factors, such as yield and the processing speeds of equipment. Additionally, it simulates random disruptions like equipment breakdowns and weather conditions. It generates a comprehensive set of metrics, among which the essential ones cover the resources needed for harvesting and transportation, equipment utilization rates, fuel consumption, total dry mass harvested, operational costs, and the anticipated duration to finalize the harvest with the available resources.

1. INTRODUCTION

The IBSAL 2.0 model framework has been developed using ExtendSim, a discrete event simulation (DES) tool, because of the inherent randomness of many essential system variables, including yield, processing rates, travel speeds, and delays arising from equipment failures and weather. Certain studies necessitate the inclusion of all random parameters, while others require only a subset. For instance, feedstock yield may be a random variable when examining inventory, but a deterministic value adjusted by scenario might be employed to analyze its impact on harvesting cost.

DES models also allow us to quantify delays due to resource competition. For example, the transport crew consists of a few semi-trucks with trailers that move the feedstock from the field side to the refinery. The transport crew also includes a loader on the field to load the switchgrass bales onto the trailer. If the storage facility is 30 miles away, and the transport crew consists of two trucks and one loader, the loader would likely be sitting idle most of the time, waiting for the trucks to travel to and from the storage facility. On the other hand, if the transport crew consists of 40 trucks and one loader, the loader will be 100% busy, while the trucks will likely be sitting idle in line at the field most of the time, waiting on the loader. Our DES model can be used to determine appropriate crew configurations in this queuing system.

DES models also allow us to quantify delays due to random events, such as equipment failures and weather. Weather, for example, becomes a significant factor when working within a limited harvest window. Everyday weather events, like precipitation, can prevent harvesting crews from working on the field. While a single precipitation event may not influence the system, a series of precipitation events on consecutive days can accumulate enough moisture in the field to halt harvesting operations. DES models can use historical weather data or representative distributions to mimic the effects of weather delays on harvesting operations.

However, the IBSAL 2.0 model does not account for every detail in the feedstock supply chain. We have used simplifying assumptions because the model is for strategic rather than operational decisions. For example, a crew in the model might work eight hours per day, five days a week, or 12 hours per day for seven days a week. In the latter scenario, we’re not recommending every employee work 84 hours per week, but two employees could staff it. The model should not be used to schedule employees but to model the time the equipment operates in the field. We assume reasonable management practices are in place for the employees who operate the equipment.

The popular and widely used IBSAL model was developed over a decade ago (Sokhansanj et al., 2009). It was flow-oriented with detailed logic for each operation. The items flowing through the model began as individual bales, then batched by load and moved to the field side, then batched by load and moved to storage. This structure meant there could be as many as 800,000 items flowing through the model, which resulted in slow run times.

IBSAL 2.0 uses a different modeling paradigm for modeling the feedstock supply chain. Although both tools were developed in ExtendSim, IBSAL 2 uses an internal database to improve efficiencies and reduce run times (Diamond et al., 2010). In IBSAL 2.0, items represent the various harvest and transport crews and their related equipment. Regardless of crew type, each crew item flows through the same generic process. This process includes finding a field for the crew, moving the crew to the assigned field, and using the crew equipment items to process the field before returning them to the beginning of the loop for their next field assignment. Various field-related database tables contain the fields' input and output properties. Each record in the *Field Status* table represents a specific field or land area where the feedstock is grown in the supply shed. The *Field Status* table contains properties containing the field's size, yield, amount to harvest, and bales harvested. The crew items interact with the *Field Status* table during the harvest and transport operation instead of batching and unbatching bale items. This change in model structure from IBSAL to IBSAL 2.0 has dramatically reduced the model run time and allows for more experimentation possibilities.

In addition to speed, this structure and its internal database make it easy to convert the model from one feedstock to another. There is nothing feedstock specific in the process flow of the model. The model database contains all feedstock-specific information, so the model's input data is the only difference between the switchgrass, corn stover, poplar, or pine.

2. MODEL NAVIGATION

You will find buttons to open the primary database tables at the top of the main model worksheet. These buttons are links to the most important tasks a user would need to interact with the model, whether running the model or opening the primary input and output tables. Figure 1 contains the model worksheet with buttons to access the most frequently used tables. The buttons are arranged in a grid. The first column includes buttons for essential model control; the others provide links to open specific tables described in Table 1. The rows for the input, status, and output columns are organized by object type. The object type includes the model, crew type, crew, crew equipment, field, and field grid.

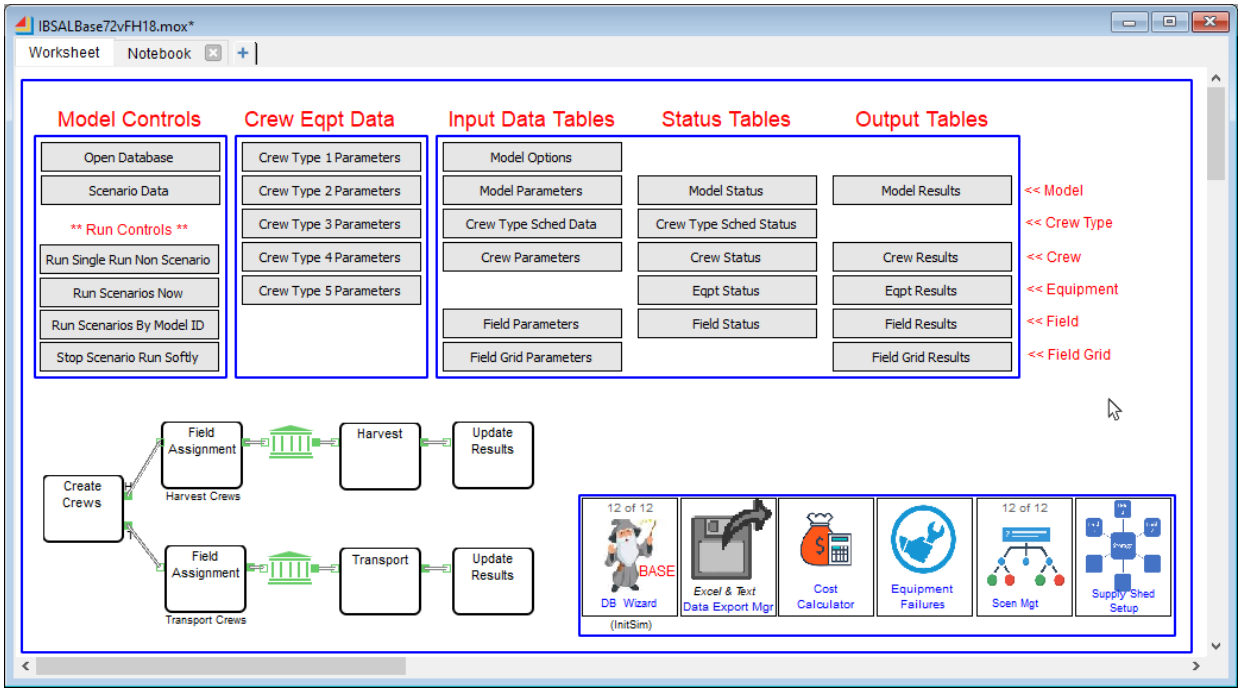


Figure 1. Main model worksheet and user interface of the model.

Table 1. Columns of buttons on the main model worksheet

Column\Data Type	Description
Model Controls	Includes buttons for opening the database, the *Scenario Data* table, and running the model with and without scenario management.
Crew Eqpt Data	Includes buttons to open the crew equipment tables by crew type.
Input Data Tables	Includes buttons to open the most used input tables.
Status Tables	Includes buttons to open the primary status tables. The status tables report the current state of the objects.
Output Tables	Includes buttons to open the most used output tables.

The harvest and transport crew item flow is found just below the buttons on the model worksheet in Figure 1. There is a common crew creation construct for both harvest and transport crews. Then, the crews are separated, so the harvest crews go through the top path and the transport crews through the bottom. Harvest and transport crews show a similar high-level process flow, but there are distinct differences inside the h-blocks. Transport crew equipment events are based on trucks traveling to and from the field, while the harvest crew equipment events are based on hourly field processing intervals. The harvest and transport crew workflow includes the following h-block constructs:

- Create Crews (crew item)
- Field Assignment (crew item)
- Processing

    - Harvest for harvest crews (crew equipment item)
    - Transport for transport crews (crew equipment item)
- Update Results (crew item)

The lower right portion of the main model worksheet contains several custom blocks and hierarchical blocks (h-blocks). Custom blocks are used in ExtendSim when writing code is more straightforward than developing an elaborate construct using blocks. H-blocks are used in ExtendSim to consolidate a group of blocks to present it better to the user. Table 2 contains the list of blocks and h-blocks in this section. However, model users do not need to interact with these blocks as they primarily work through the database tables.

Table 2. List of custom blocks and h-blocks on the bottom right corner of the main model worksheet

Block \ h-block	Description
DB Wizard	Sets up the model database at the beginning of each run and compiles the results at the end.
Data Export Mgr	Exports selected tables to text or Excel at the end of the simulation. Chapter 6 provides more detail.
Cost Calculator	Calculates the crew equipment costs at the end of each run. The equipment costs are calculated based on the ORNL Cost Methodology Report (Turhollow et al., 2009).
Equipment Failures	Contains the construct for equipment failures. Chapter 4 provides more detail.
Scenario Mgr	Sets up scenarios for an experiment. Chapter 5 provides more detail.
Supply Shed Mgr	Sets up the supply shed for each run based on the feedstock needed, the feedstock properties, and the field properties.

3. MODEL ARCHITECTURE

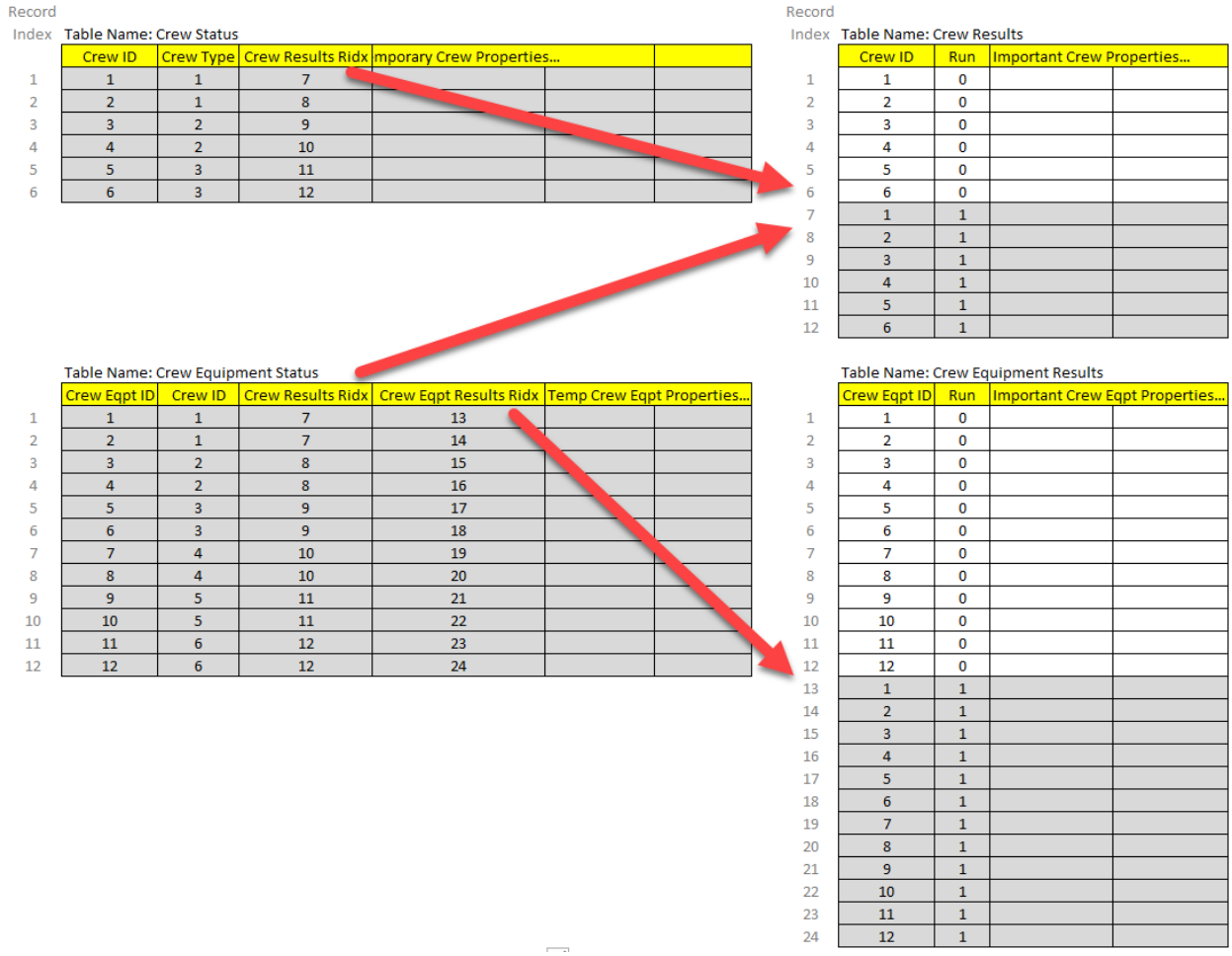
3.1 ITEMS

Items in the IBSAL 2.0 model represent harvest crews, transport crews, crew equipment, and equipment failures. A crew item is a collection of specified equipment that performs an operation or task on the field or at the refinery. For example, a baling crew item in a switchgrass model might consist of three baler crew equipment items. The baler crew equipment item includes a tractor and the implement as a set. The crew item and its crew equipment items do not exist in the model simultaneously. The crew item exists when the crew is waiting for their next field assignment and while traveling to the field. The crew equipment item exists only when the crew is processing a field.

3.2 SIMULATION DATABASE STRUCTURE

Most items in the IBSAL 2.0 model are tightly connected to one or more corresponding database tables. Many crew and crew equipment properties are contained in the database instead of an item's attribute. The new database design sets up the crews and crew equipment to be more of an agent-based modeling tool (Law, 2015). This architecture allows easy access to all vital crew and crew equipment data, enabling the output properties to be easily exported at the end of a run. For example, the amount of fuel each crew equipment item has consumed for the harvest season is reported in the *Crew Equipment Results* table by

equipment and by run number, which can be easily accessed at the end of a run. Such information would be difficult to access at the end of a run if it was only recorded on an item's attribute.



Record Index — Table Name: Crew Status

	Crew ID	Crew Type	Crew Results Ridx	mporary Crew Properties...		
1	1	1	7			
2	2	1	8			
3	3	2	9			
4	4	2	10			
5	5	3	11			
6	6	3	12			

Record Index — Table Name: Crew Results

	Crew ID	Run	Important Crew Properties...	
1	1	0		
2	2	0		
3	3	0		
4	4	0		
5	5	0		
6	6	0		
7	1	1		
8	2	1		
9	3	1		
10	4	1		
11	5	1		
12	6	1		

Table Name: Crew Equipment Status

	Crew Eqpt ID	Crew ID	Crew Results Ridx	Crew Eqpt Results Ridx	Temp Crew Eqpt Properties...	
1	1	1	7	13		
2	2	1	7	14		
3	3	2	8	15		
4	4	2	8	16		
5	5	3	9	17		
6	6	3	9	18		
7	7	4	10	19		
8	8	4	10	20		
9	9	5	11	21		
10	10	5	11	22		
11	11	6	12	23		
12	12	6	12	24		

Table Name: Crew Equipment Results

	Crew Eqpt ID	Run	Important Crew Eqpt Properties...	
1	1	0		
2	2	0		
3	3	0		
4	4	0		
5	5	0		
6	6	0		
7	7	0		
8	8	0		
9	9	0		
10	10	0		
11	11	0		
12	12	0		
13	1	1		
14	2	1		
15	3	1		
16	4	1		
17	5	1		
18	6	1		
19	7	1		
20	8	1		
21	9	1		
22	10	1		
23	11	1		
24	12	1		

Figure 2. Illustration of basic indexing concepts applied throughout the model database. Most status tables contain one row per object, while the result tables contain one row per object per run.

There are just a few simple concepts to understand about the database to find almost any parameter quickly, and they have been applied consistently throughout the database. These concepts are discussed from the perspective of the crew and crew equipment tables shown in Figure 2. There are often temporary data that we must keep track of throughout a run. For example, a harvesting crew must be able to store the field ID it is currently harvesting and when the crew began harvesting its current field. The information is not an input to the model, nor does it need to be reported as output. It is the current state of the crew, and the *Crew Status* table contains this information. The *Crew Status* table includes one record per crew item; its record index will be the same as its crew ID. The output collected on the crew items is collected across runs and found in the *Crew Results* table. Notice in Figure 2 that the *Crew Status* table has six records, one for each of the six crew items. However, the *Crew Results* table contains 12 records, one for each crew item per run. The results record index does not directly correspond to the same record in the status table because we collect the results across multiple runs. However, the structure of the status tables makes it convenient to store the current results record index, thus eliminating the need to search for the results record indices inefficiently.

Both harvest and transport crews are implemented as items. The model contains one item per crew. Every crew is assigned a unique crew ID attribute, *aCrwID*. The crew ID attribute is the crew item's record index when updating its status in the *Crew Status* table. Every crew item is also assigned an attribute *aCrwRsltsRIdx*, which points to the record index in the *Crew Results* table, where it posts the results. The results are updated as crew items are passed through an Equation (I) or Write (I) block; the construct uses the attribute reference for the results record index. If a custom block updates the results, the construct will use the *Results RIdx* field in the status table to reference the results record index.

The crew equipment tables are set up similarly to the crew tables. Figure 2 shows the *Crew Equipment Status* table has 12 records, one for each of the 12 crew equipment items. However, the *Crew Equipment Results* table contains 24 records, one for each crew equipment item per run. Crew equipment items use attributes *aEqptID* and *aEqptRsltsRIdx* and work similarly as the corresponding crew attributes *aCrwID* and *aCrwRsltsRIdx*.

This same database structure applies to more than items in the model. We can consider crews and crew equipment similar to classes in an object-oriented programming perspective. Both crews and crew equipment are implemented using items. Each instance of the crew and crew equipment class is considered an object, and they have a physical item representation in the model and database records. We can also consider a field (land in the supply shed where feedstock is grown) as a class, but it has a different implementation than crews and crew equipment. The field objects only have a database implementation, no item implementation. The field objects in the *Field Status* and *Field Results* tables follow the same database principles as the crew and crew equipment objects. There's one record per field in the *Field Status* table; each field object corresponds to a specific record in the *Field Status* table, and one record per field per run in the *Field Results* table.

Table 3. List of classes in the model and the tables associated with the class

Class	Item	Parameter	Status	Results
Model	No	Model Parameters Model Options	Model Status	Model Results
Crew Type	No	Crew Type Data		
Crew	Yes		Crew Status	Crew Results
Crew Equipment	Yes		Crew Eqpt Status	Crew Eqpt Results
Field	No	Field Parameters	Field Status	Field Results
Field Grid	No	Field Grid Parameters		Field Grid Results

Most of the "classes" in the model have a similar structure, not identical, but similar. Most of the classes include the corresponding tables, e.g., "class" Parameters table, "class" Status table, or "class" Results table. Table 3 lists the classes and indicates the corresponding tables related to the class.

4. MODEL LOGIC

4.1 BIOMASS SUPPLY SHED SETUP

Two different approaches can be taken to set up the biomass supply shed. The supply shed could use actual field data that have been identified and selected by a GIS tool, or the supply shed could use generic fields randomly chosen from a landscape grid. Both approaches have pros and cons and should be selected based on the project requirements.

Actual field data from a GIS tool can provide yield estimates by field based on specific land characteristics. GIS data also allows for precise transportation distance estimates along the road network. However, this requires additional effort to select fields for a supply shed in a GIS tool and should be repeated many times to generate the appropriate statistics.

The necessary steps to set the model up for actual field locations are listed below:

- Uncheck the "Update Grid Distances Annually" option in the SS Setup block.
- If manually setting up fields:
    - Open the *Field Grid* table and adjust the number of fields by changing the number of records.
    - Set the distance from the refinery to the field for each field by copying the distance from the GIS tool or Excel and pasting the data into the table.
    - Set the yield by field if the yield differs based on the field characteristics.
- If setting up the fields through an atomic import:
    - Add the Data Import block to the model worksheet and set it up to import the data automatically into the *Field Grid* table. Ensure the data is in the same format as the *Field Grid* table.

The model can also automatically create the fields using a generic landscape. The benefit of using a supply shed with randomly selected fields from a generic landscape grid is that it is easy to regenerate a new supply shed on every model run to study supply shed parameters like yield, field size, and landscape density. We can reasonably approximate most regions by adjusting the yield, field size, and density.

The steps required to generate a supply shed automatically are listed below:

- Check the "Update Grid Distances Annually" option on the SS Setup block.
- Set the following options in the *Field Grid Parameters* table.
    - One Field Per X KM2 – sets the field density for the feedstock in the supply shed by allowing it to select, on average, one field per x square kilometers.
    - Distance Factor – sets a factor representing the distance a vehicle will travel between the field and the refinery. The default value is 1.4.
- Set the following parameters in the *Field Parameters* table.
    - Number of Fields – sets the number of fields the model will set up for the run.
    - Field Size – sets the desired field size in hectares.

The following equations are used to set up the supply shed:

$$A_{feedstock} = \frac{D_{Refinery}}{Yield} \tag{1}$$

$$A_{SupplyShed} = \frac{Harvest\ Rotation * A_{Feedstock}}{P_{Feedstock}} \tag{2}$$

$$R_{SupplyShed} = \sqrt{\frac{A_{SupplyShed}}{\pi}} \tag{3}$$

$$N_{Fields} = \frac{A_{Feedstock}}{A_{Fields}} \quad (4)$$

Where:

- $A_{Feedstock}$ – The area required for feedstock harvesting annually in units of hectares.
- $D_{Refinery}$ – The annual refinery demand in units of dry megagrams.
- Yield – average feedstock yield in units of megagrams per hectare.
- Harvest Rotation – frequency of harvest events.
- N_{Fields} – The number of fields required to harvest annually.
- A_{Field} – The average area of a field in units of hectares.
- $A_{SupplyShed}$ – The average area of supply shed in units of hectares.
- $P_{Feedstock}$ – The fraction of land in the supply shed dedicated to growing the feedstock.
- $R_{SupplyShed}$ – The supply shed radius in units of kilometers.

Equation 1 calculates the estimated area in units of hectares necessary for growing the feedstock required to support the refinery annually. The refinery demand should be adjusted to account for dry matter yield loss while the feedstock remains in storage. In some cases, the yield value used should consider the year-to-year variability. It is also important to note that the feedstock yield is not the above-ground yield of the plants but rather the yield that can be captured during the harvest process.

Equation 2 calculates the estimated area of the supply shed, which includes the land dedicated to growing the feedstock and all the land contained in the supply shed. The harvest rotation should be set to one for feedstocks with annual harvest events, three or four for coppice feedstocks, and seven or more for single-stem trees with a long growth cycle. This calculation (Equation 2) is used by Equation 3 to determine the radius of the supply shed or the distance to the outermost fields. The maximum radius is used when randomly selecting fields. Equation 4 calculates the number of fields required to be harvested annually to support the annual refinery demand based on the total land needed to grow feedstock and the average field size, where both terms are in units of hectares.

Equations 1 through 4 provide the required parameters (number of fields and supply shed radius), allowing us to set up the fields in the automatic supply shed generation method, as illustrated in Figure 3, where each black dot represents a potential field in our supply shed, the biorefinery located at the center, and the supply shed radius, illustrated by the red circle. The possible fields are placed 1 kilometer apart in the X and Y directions. The potential field locations are within the supply shed radius calculated from Equation 3. All the grid locations outside the maximum supply shed radius are excluded from the selection process.

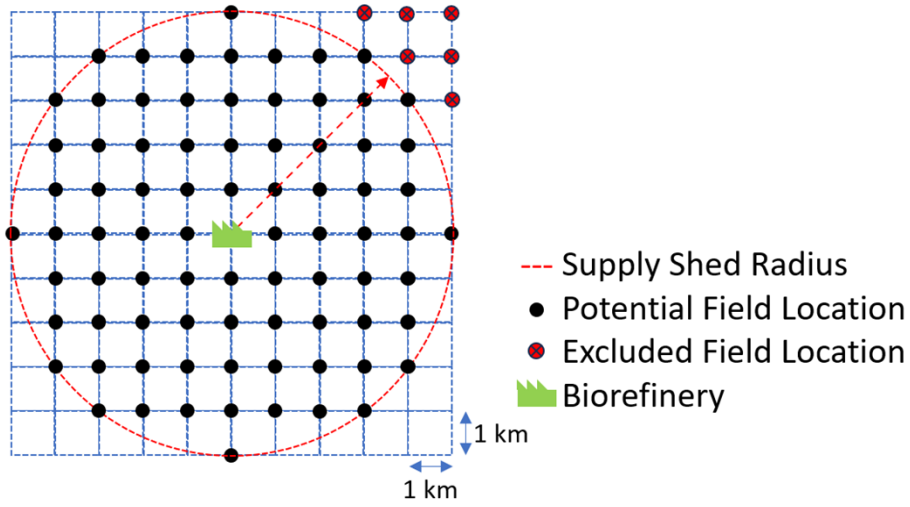


Figure 3. Field grid illustration to select fields in a supply shed. Each black dot represents a potential field location, and the red circle symbolizes the maximum supply shed radius.

The grid is set up in an array containing each potential field's X and Y positions. This array is shown in Table 4. The direct distance to each grid location (distance as the crow flies) is calculated using Equation 5. The estimated road distance to each grid location (distance by road) is calculated using Equation 6. We can assume that the road network within the supply shed will never support a direct path from the field to the refinery, so the direct distance is adjusted by a road factor, which we typically assume to be 1.4.

$$Distance_{Direct} = \sqrt{X^2 + Y^2} \tag{5}$$

$$Distance_{Road} = Road\ Factor * Distance_{Direct} \tag{6}$$

To randomly select fields from the grid array, each grid position is given a random number between 0 and 1, as shown in the *Random Number* column in Table 4. Then, the grid array is sorted on the random number column. Once sorted, the top grid locations are used as the randomly selected fields for the current simulation run. The number of fields selected is based on the calculation from Equation 4.

Table 4. Example of the grid array of possible field locations including X and Y coordinates, distance to the refinery by direct distance, estimated road network, and a random number used for field selection

X	Y	Direct Distance (Km)	Distance by Road (Km)	Random Number
0	5	5.000	7.071	0.938
-3	4	5.000	7.000	0.889
-2	4	4.472	6.261	0.858
-1	4	4.123	5.772	0.880
0	4	4.000	5.600	0.377
1	4	4.123	5.772	0.452

2	4	4.472	6.261	0.351
3	4	5.000	7.000	0.218
-4	3	5.000	7.000	0.531
-3	3	4.243	5.940	0.854
…	…			

4.2 CREW TYPES

Five crew types are set up in the IBSAL 2.0 model. The first four are harvest crew types, and the last is a transport crew type. Crew types can be renamed from the *List Crew Types* table shown in Figure 4. The crew-type names are used mainly as labels or descriptions for the data in many tables. Table names and field names that refer to specific crew types are labeled as crew type 1 through crew type 5, which relates to the record number in the *List Crew Types* table.

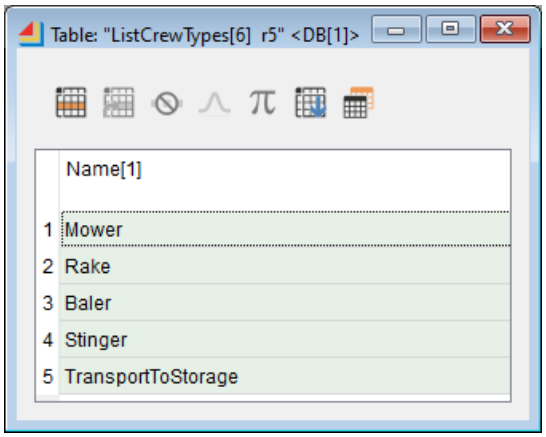


Figure 4. The *List Crew Types* table allows the user to rename crew types.

The crew types can be adjusted using the *Use* checkbox in the *Crew Type Data* table shown in Figure 5. If, for example, crew type 2, a rake, in this case, is unnecessary, then uncheck the box beside the rake record, which will turn off the use of crew type 2 in the model. The number of crew types can be increased, but additional model development would be required.

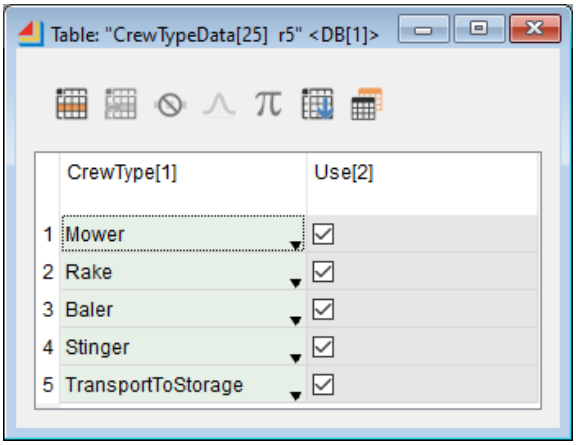


Figure 5. *Crew Type Data* table allows users to enable and disable crew types.

The IBSAL 2.0 model assumes only one crew is allowed on a field, which has two implications. First, once a crew of a given crew type selects the field, no other crews of that type will be allowed to help process the field. Secondly, the next crew type cannot start processing a field until the last crew type has completed the field. A field will not become "available" for consideration by the next crew type until the previous crew type has finished. In the actual switchgrass system, the rake crew might start raking the field the day after the mowing crew started mowing the field even though the mowing crew is not finished; however, we do not need to model what happens in the actual system explicitly. Having the raking crew show up a few days later is a close enough approximation in most cases.

4.3 HARVEST CREWS

The IBSAL 2.0 model assumes that only one crew is allowed on a field at a time, leading to two important implications. Firstly, once a crew of a specific type selects a field, no other crew of the same type can assist in processing that field. Secondly, the next crew type cannot process the field until the previous crew type completes its work. While the actual switchgrass system might have the rake crew starting their work the next day after the mowing crew starts, we don't need to explicitly model this delay, as having the raking crew show up a few days later is usually a close enough approximation.

The harvest crews process feedstock on the field by following the steps illustrated in Figure 6. They are first created in the Create Crews h-block and then proceed to the Field Assignment h-block, where they await their next field assignment. Once assigned, they move on to the Harvest h-block to process their designated field. Afterward, they move to the Update Results h-block, where the model, crew, and field results are updated. Finally, they return to the Field Assignment h-block to wait for their next field assignment. This loop continues as long as there are fields left to be harvested.

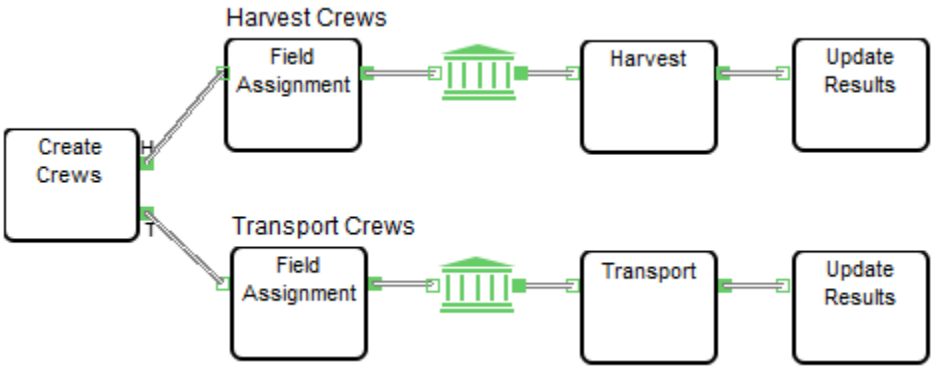


Figure 6. The process flow of the crews on the main model worksheet.

When a harvest crew reaches their assigned field, they are unbatched into a specific number of crew equipment items. The crew equipment items independently process the field, as shown in Figure 7. Once the field is completely processed, the crew equipment items are batched, and the results are updated before they are given their next field assignment.

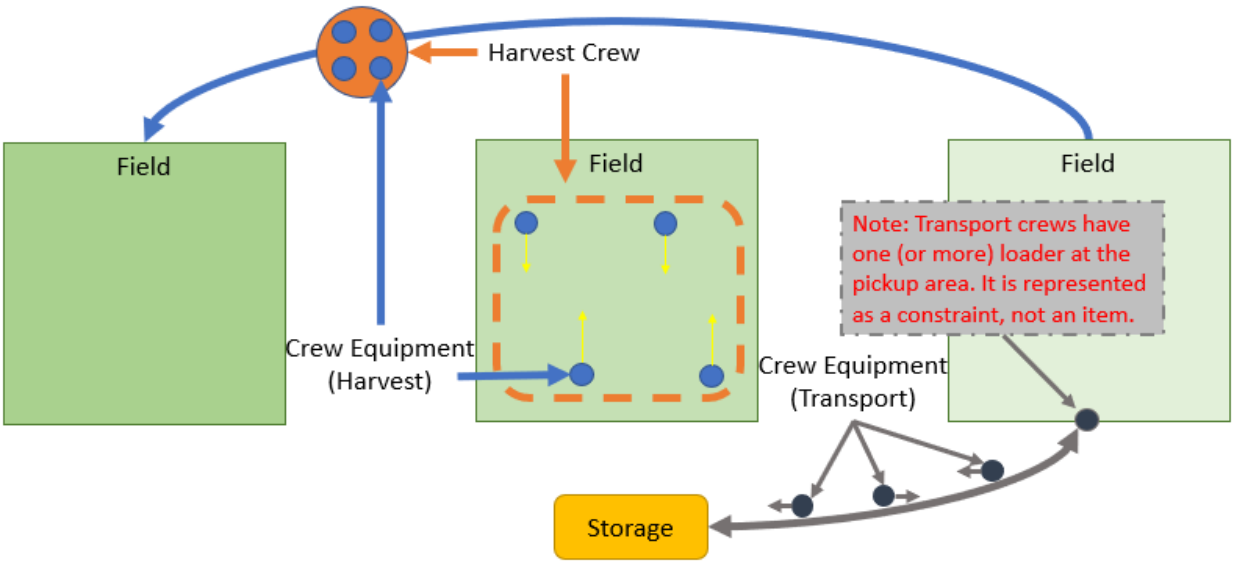


Figure 7. Illustration of a harvest crew unit with four crew equipment items processing a field. Afterward, the crew unit moves to the following field to process.

The processing of fields by the harvest crew equipment items occurs in one-hour increments. The processing rate can be set in the *Crew Type X Eqpt Parameters* table, where X corresponds to the crew type ID ranging from 1 to 5. For instance, the *Crew Type 1 Eqpt Parameters* table, shown in Figure 8, provides the processing rate, which can be supplied as a field capacity or material capacity or calculated using speed, width, and operational efficiency. The model selects the slower rate if both field and material capacities are provided.

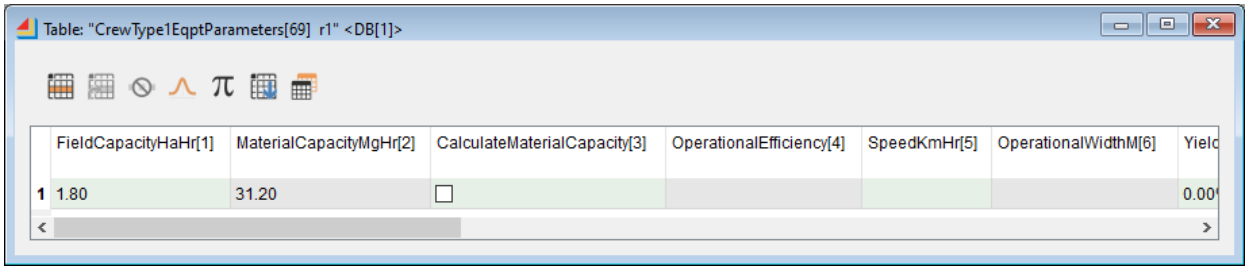


Figure 8. *Crew Type 1 Eqpt Parameters* table contains operational parameters related to crew type 1.

The number of crews and crew equipment items per crew for each crew type are defined in the *Crew Parameters* table, as shown in Figure 9. For example, crew type 1 consists of 17 crews (*NumCrewType1* field), with each crew type 1 having three mowers (*NumEqptPerCrewType1* field). As a result, there would be 51 mowers in the supply shed to mow the fields.

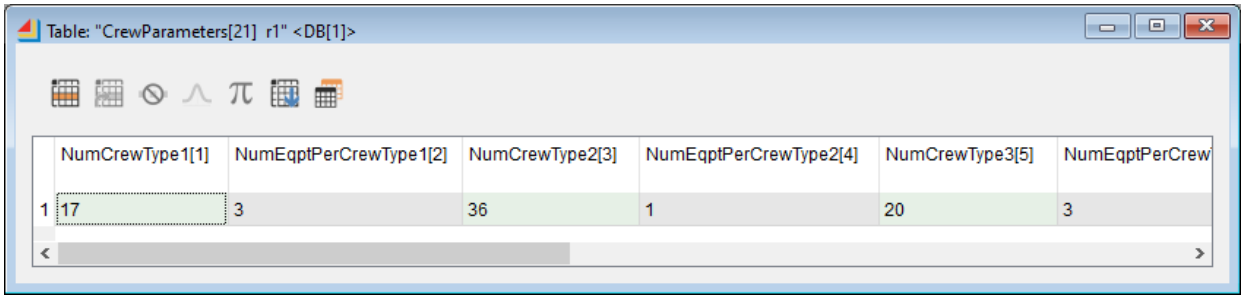


Figure 9. The *Crew Parameters* table contains the number of crews and the amount of equipment per crew for each crew type.

The crew and crew equipment items are tracked in the database and recorded in separate tables. The crew equipment tables hold data specific to each crew equipment item, while the crew tables contain information about the entire crew. For instance, the time until the subsequent failure or repair event is specific to an individual equipment item and would be found in the crew equipment tables. On the other hand, the time a crew starts processing a field is consistent for all equipment in the crew, so it is contained in the *Crew Status* table. Additional details regarding the structure of these tables are provided in the Database Structure section.

Aside from the primary version described above, there is a second variation of harvesting logic in the IBSAL 2.0 model architecture. In this alternate approach, a more intricate harvesting process is modeled, where forage harvesters require wagons to simultaneously be present in the field. This combination of harvesters and wagons works together to process the field. The forage harvesters are represented as individual items, while the wagons form a pool from which the harvesters can draw. A forage harvester must always have an available wagon with sufficient capacity "attached" to it.

During harvesting, the forage harvesters blow the feedstock into the wagon. When a wagon becomes full, or the harvester approaches the field edge and reaches more than 65% capacity, the wagon detaches from the harvester and heads to the feedstock pile to unload the collected feedstock. The harvester then selects the next available wagon to continue the harvesting process.

To optimize the system's efficiency, wagon operators on the field know when a harvester needs their next empty wagon. Wagon operators position themselves strategically to minimize the wait time for the harvesters to receive an empty wagon. The model emulates this behavior without involving complex prepositioning decision-making.

The model maintains a queue of empty wagons at the field edge after they finish unloading the feedstock. When a harvester requires the next wagon, it evaluates the waiting times of the wagons in the empty wagon queue. The harvester calculates the travel time from the empty wagon queue to its location and compares that time with the waiting time of each wagon in the queue. The travel time to the harvester from the wagon queue is illustrated in Figure 10.

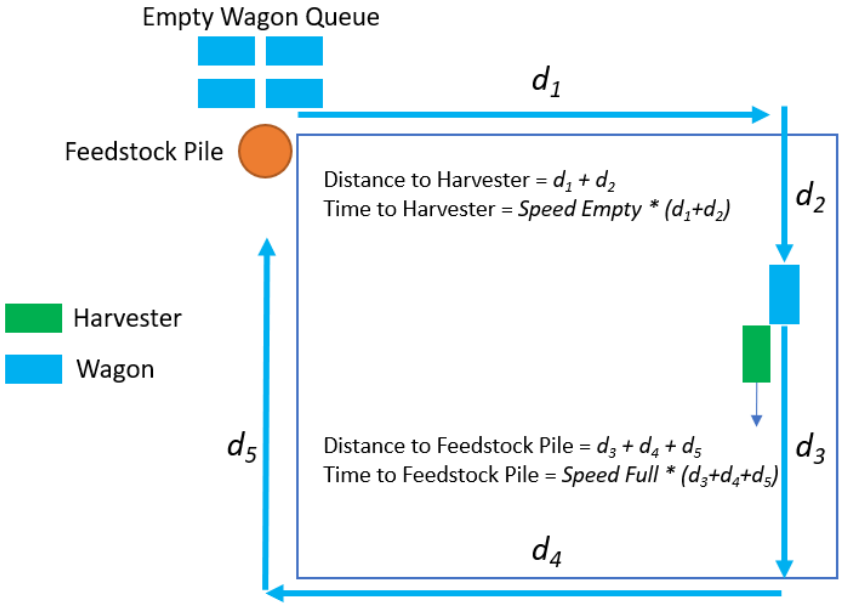


Figure 10. The travel time calculation for the wagons as they travel between the empty wagon queue and the harvesters.

Based on this evaluation, the harvester selects a wagon waiting in the queue as long as or longer than it would take to travel to the harvester's location in the field. In cases where the maximum wait time of the available wagons is less than the travel time to the harvester, the harvester picks the longest waiting wagon. It then considers the additional time required for the remaining wagon travel time and pauses processing accordingly. This approach helps ensure a smooth and efficient harvesting process.

4.4 TRANSPORT CREWS

Transport crews have a different flow path. Transport crews are created in the same construct as the harvest crews but proceed to a different Field Assignment h-block, as shown in Figure 6. The transport crews move to the Field Assignment h-block, where they wait for a field assignment. Then, the transport crews move to the Transport h-block, where they move the feedstock from the assigned field to storage. Next, they move to the Update Results h-block, where the model, crew, and field results are updated.

Finally, they return to the Field Assignment h-block to wait for their next assignment. Transport crews repeat this loop as long as there remain untransported fields.

The transport crews go through a loop similar to the harvest crews; however, the harvest and transport constructs differ fundamentally. The harvest crews are processing the fields in one-hour chunks at a time. Each truck in the transport crew operates independently while repetitively performing several steps to transport the feedstock. These steps are listed below.

- Travel to the field (from refinery/storage)
- Queue to wait on loader (at field)
- Get loaded by loader (at field)
- Travel to refinery/storage (from field)
- Unload (at refinery/storage)
- Test end-of-shift travel restriction

The trucks will repeat this loop throughout their shift until approximately one hour before the end of their shift. The *Stop Travel X Hours Before End of Shift* parameter in the *Crew Type Schedule Data* table has a default value of one hour, but this can be adjusted. The truck checks the time until the end of the shift just before it leaves the refinery/storage area to get its next load. If it is past the end of the shift travel cut-off time, the truck will not leave the refinery/storage area. Instead, it will go off shift for the day.

The model assumes one loader at the field; therefore, only one truck can load at a time. This parameter can be adjusted in the *Crew Type 5 Eqpt Parameters* table in the *Num Loaders at the Field Site* field. However, unless the fields are near the refinery or there is an excessive number of trucks per transport crew, the default setting of one is usually best. If this changes, adjustments must be made to the cost calculation of the loader, which can be done using the associated *Equipment Cost RIdx* field in the *Crew Type 5 Eqpt Parameters* table. It's set up assuming there is just one loader at the field.

There is no constraint for unloading at the refinery. It is a shared resource among all transport crews, and we assume the cost burden is a part of the refinery/storage facility. If this assumption needs to be adjusted, additional model development work will be required.

4.5 FIELD ASSIGNMENT

Both harvest and transport crews wait in the Field Assignment h-block until they are assigned their following field to process. The default field assignment is made by selecting the first field available in the *Field Status* table that requires the crew's type. After the field assignment is made, the crew will travel to the field and begin processing the field.

The field assignment is implemented using the Queue Equation block. When the Queue Equation block wakes up, it will start a loop to evaluate each crew item in the queue for its following field to process. The search involves looping through the *Field Status* table for a field that is a) not currently being processed and b) requires the crew's crew type next. However, if the crew type is currently off shift or has already passed the available daily travel time, that crew skips the field search for that period.

The triggering mechanism that wakes up the Queue Equation block to evaluate the crew items is complex. If the model is modified significantly, the Queue Equation should be carefully verified afterward. If overlooked, this could result in crews sitting idle while available fields are ready to be harvested by the

idle crew, which would delay the completion of the harvest. The Queue Equation block wakes up to assign crews to fields during the following events:

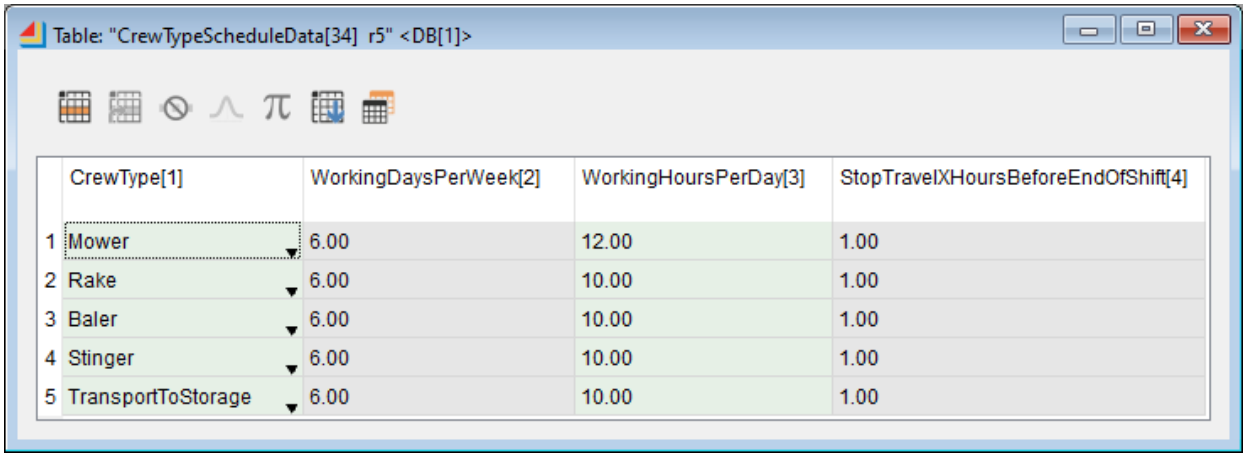
- a new crew enters the Queue Equation block
- a crew gets assigned to a field and leaves the Queue Equation block
- any shift status of a crew type changes
- any travel status of a crew type changes
- any field status changes

The field selection process prioritizes the fields based on their field ID. The search for the following field begins at the top of the *Field Status* table. Once found, the harvest crew uses a default travel time value set in the *Crew Parameters* table, *Time Between Fields* field. The default time is designated as a uniform distribution between one and two hours.

The following field search logic does not consider the distance between fields when making this selection. This search algorithm could be set up using the field coordinates to minimize the distance between fields. However, it would then require the traveling salesman optimization algorithm to determine the shortest path trip for each crew in the field harvesting order. In practical application, however, most harvesting crews will coordinate amongst themselves to minimize travel time rather than use advanced optimization techniques. So, using a simple time between fields parameter is a reasonable rough approximation as we are primarily concerned with how much time the equipment spends in the field harvesting.

4.6 CREW AVAILABILITY \ SHIFTS

Shifts are set in the *Crew Type Schedule Data* table, as shown in Figure 11. Crew shifts are set by crew type, so every crew of a given type is set to the same shift.



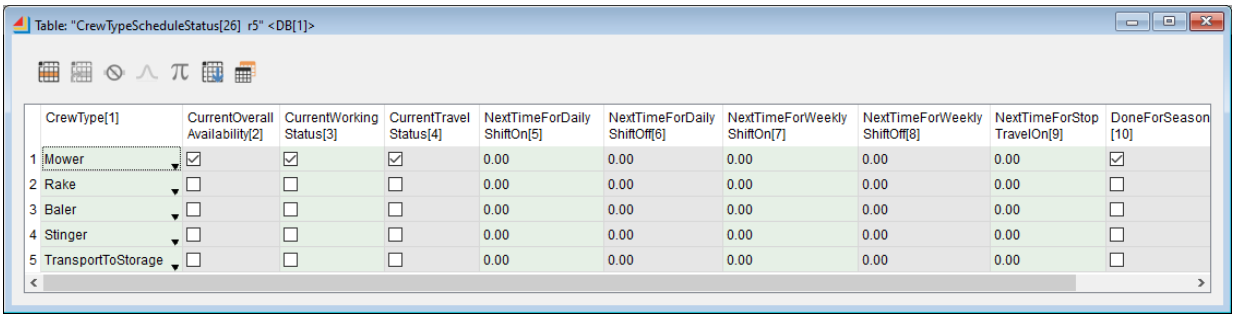
	CrewType[1]	WorkingDaysPerWeek[2]	WorkingHoursPerDay[3]	StopTravelXHoursBeforeEndOfShift[4]
1	Mower	6.00	12.00	1.00
2	Rake	6.00	10.00	1.00
3	Baler	6.00	10.00	1.00
4	Stinger	6.00	10.00	1.00
5	TransportToStorage	6.00	10.00	1.00

Figure 11. The *Crew Type Schedule Data* table contains the shift-related parameters by crew type.

Three parameters are required to set up the shift of a crew type. They include the following:

- Working Days per Week – Sets the number of working days per week for the crews of the specified crew type.
- Working Hours per Day – Sets the number of working hours per day for the crews of the specified crew type.
- Stop Travel X Hours Before End of Shift – the number of hours before the end of the shift when traveling must stop. For transport crews, it is evaluated before departing the refinery. For harvest crews, it is assessed before traveling to a new field.

The current shift status for each crew type during the model run can be found in the *Crew Type Schedule Status* table, as shown in Figure 12.



	CrewType[1]	CurrentOverall Availability[2]	CurrentWorking Status[3]	CurrentTravel Status[4]	NextTimeForDaily ShiftOn[5]	NextTimeForDaily ShiftOff[6]	NextTimeForWeekly ShiftOn[7]	NextTimeForWeekly ShiftOff[8]	NextTimeForStop TravelOn[9]	DoneForSeason [10]
1	Mower	☑	☑	☑	0.00	0.00	0.00	0.00	0.00	☑
2	Rake	☐	☐	☐	0.00	0.00	0.00	0.00	0.00	☐
3	Baler	☐	☐	☐	0.00	0.00	0.00	0.00	0.00	☐
4	Stinger	☐	☐	☐	0.00	0.00	0.00	0.00	0.00	☐
5	TransportToStorage	☐	☐	☐	0.00	0.00	0.00	0.00	0.00	☐

Figure 12. The *Crew Type Schedule Status* table displays the current shift status of each crew type.

It is assumed that the model starts on Monday morning, the beginning of the first workday of the week. If the crew type works six days per week, 10 hours per day, then the crew type will start at time zero and remain working until hour 10. It then stops working at hour 10 and remains off until hour 24. This daily shift will repeat for six days and stay off all day on day seven.

The model applies a constraint that limits a crew's activity when nearing the end of their shift, which is contained in the *Stop Travel X Hours Before End of Shift* parameter. The default value is set to one hour but can be adjusted. If harvest crews find a new field to harvest with less than X hours remaining in their workday, they will not begin their travel until the following workday. For transport crews, this same test is applied just before a transport crew departs the refinery/storage area traveling to a field. The transport crew will not leave the refinery/storage area until the following workday if it is past the end-of-shift travel cut-off time. Once a crew begins travel, though, it will complete the travel before going off shift, even if the end of the shift event occurs during the travel process.

4.7 EQUIPMENT FAILURES

Equipment failures are set up by specifying the mean time to failure and the mean time to repair. This data is defined by crew type in the *Crew Type X Parameters* table and is shown in Figure 13. Failure data is specified at the crew type level and implemented at the crew equipment level. We assume all equipment of a given crew type has the same failure parameters.

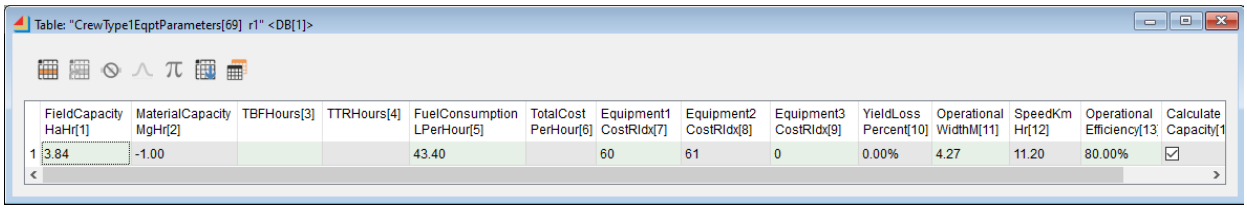


Figure 13. The *Crew Type X Parameter* table contains the time between failures and the time to repair parameters for the crew type.

At the beginning of the model run, all crew equipment is assumed to be running, and the subsequent time to failure event gets sampled from the time between failure distribution. This information is managed using the *Crew Equipment Status* table in Figure 14.

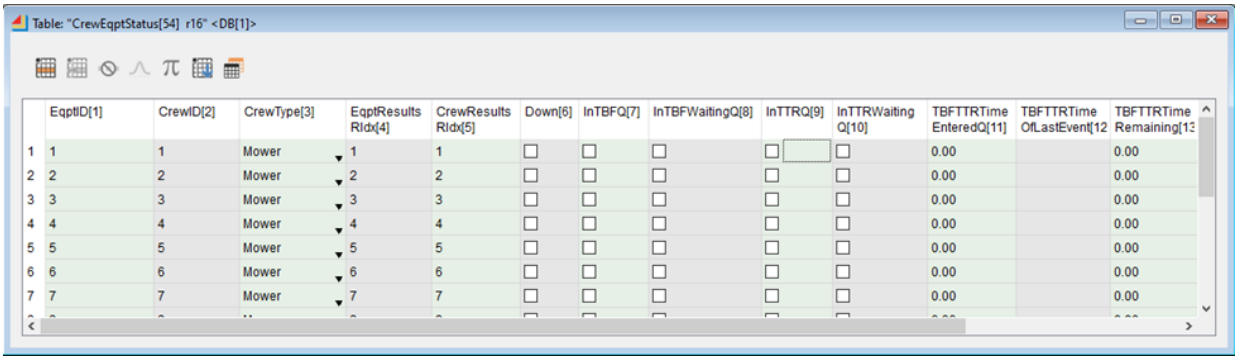


Figure 14. The *Crew Equipment Status* table contains the status of every crew equipment item.

The failure construct only considers when the equipment is on shift and processing a field. Therefore, failures do not occur during the off-shift or when the crew is waiting for a field assignment. For simplification, we have assumed failures do not happen on harvest equipment when traveling between fields.

When a crew equipment item has failed, it must be repaired during regular working hours. However, there is one instance where this rule is overlooked. Some models will include weather, which can inhibit harvesting operations. During poor weather events when harvesting operations cannot progress, we assume failed equipment will be repaired during on-shift times even though the rest of the crew is not working in the field.

When a crew finishes up a field and a failure occurs with a piece of equipment, the crew must remain on the field until the equipment is up and running again. The crew will NOT separate by leaving the failed equipment at the field while the remaining crew moves onto the following field. This strategy could be changed in the future, but it would be necessary to understand how failures are handled in the actual system.

Equipment failures are not modeled in the primary flow of the harvest or transport process. A separate construct models this at the bottom of the feedstock model in the Equipment Failures h-block. The equipment failures construct can be seen in Figure 15.

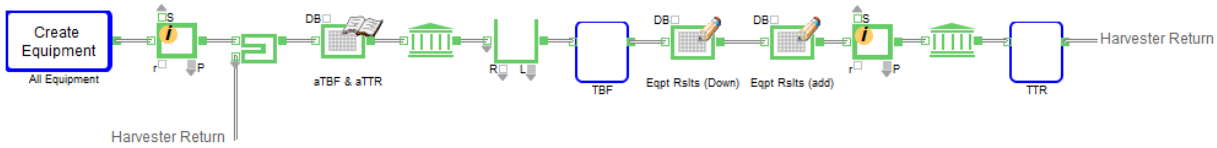


Figure 15. The Equipment Failures h-block implements the failure logic.

The equipment failures construct contains one item for every crew equipment item. The crew equipment failure items flow in a loop with two possible states. The crew equipment item can operate normally while the crew equipment failure item is in the *up* state, where the *Down* field in the *Crew Equipment Status* table is false (0). The crew equipment item will suspend its current task while the crew equipment failure item is in the down state, where the *Down* field in the *Crew Equipment Status* table is true (1). When transitioning from one state to another, the crew equipment failure item will modify the *Down* field in the *Crew Equipment Status* table. The time the crew equipment item spends in each state is dictated by the time between failure and time to repair data in the *Crew Type X Parameters* table.

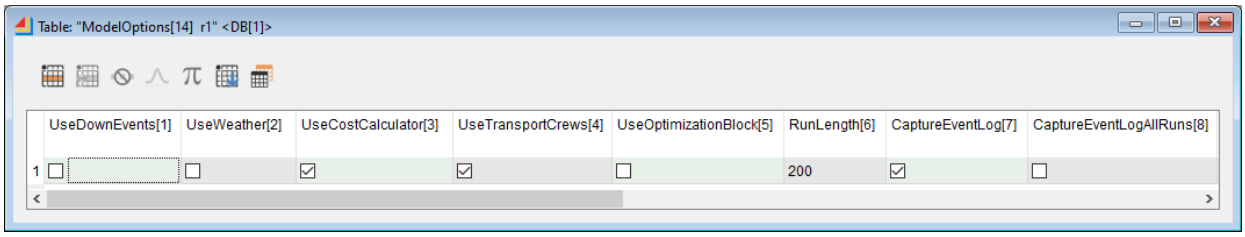


Figure 16. The *Model Options* table contains the Boolean flag to control the equipment failures.

The *Model Options* table, shown in Figure 16, contains a Boolean flag in the *Use Down Events* field, providing an easy way to control the failure logic without changing the table's failure data. The failure logic is enabled if the *Use Down Events* field is true (1). The failure logic is disabled if the *Use Down Events* field is false (0).

4.8 EQUIPMENT COST

There are two methods to incorporate the equipment cost into the model. The first method involves specifying the cost per hour for using the crew, which will be included in the *Total Cost Per Hour* field of the *Crew Type X Eqpt Parameters* table. The second method is more comprehensive and relies on calculations specified by Turhollow et al. (2009) using parameters from the *Cost Parameters* and *Cost Data* tables.

The *Cost Parameters* table includes universal equipment parameters, such as tax, housing, insurance, and interest rates. The *Cost Data* table lists equipment and relevant parameters such as purchase price, salvage value coefficients, and useful life. The *Crew Type X Eqpt Parameters* table uses their record indexes to reference the equipment in the *Cost Data* table. These indexes are used in fields like *Equipment 1 Cost RIdx*, *Equipment 2 Cost RIdx*, and *Equipment 3 Cost RIdx*, as shown in Figure 17. For instance, in the case of a mowing crew utilizing a tractor and a mower, the tractor index would be listed in the *Equipment 1 Cost RIdx* field, and the mower index would be listed in the *Equipment 2 Cost RIdx* field.

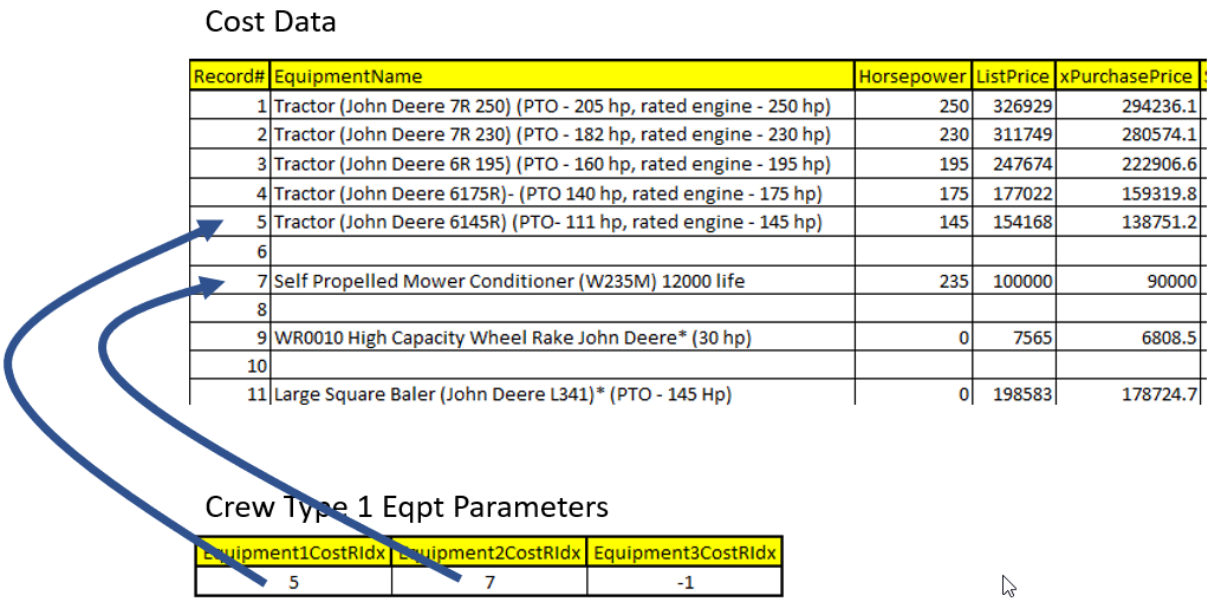


Figure 17. This figure illustrates portions of the *Cost Data* table and the *Crew Type 1 Eqpt Parameters* table, showcasing how the equipment in the *Cost Data* table is referenced in the *Crew Type X Eqpt Parameters* table.

These costs are applied based on the hours the equipment is in use. For harvest crews, the usage time includes hours spent working on the field, downtime, time spent waiting on resources, and time spent traveling between fields. For transport crews, it also consists of the time spent waiting to load and unload.

4.9 WEATHER

Weather can be set up and used in the model to simulate the lack of available harvestable days during the harvest window. Weather effects only the harvesting operations; it does not affect the transport operation (crew type 5). During a bad weather day, the harvesting operations are not allowed to work on the field during their shift; however, failed equipment can be repaired during a bad weather day.

The *Model Parameters* table contains the parameter for setting the probability of bad weather in the *Probability of Bad Weather Day* field, as shown in Figure 18. This value can range between zero and one, where zero means no bad weather days, and one indicates that every day is a bad weather day. A value of 0.15 denotes that 15% of the days are bad weather days.

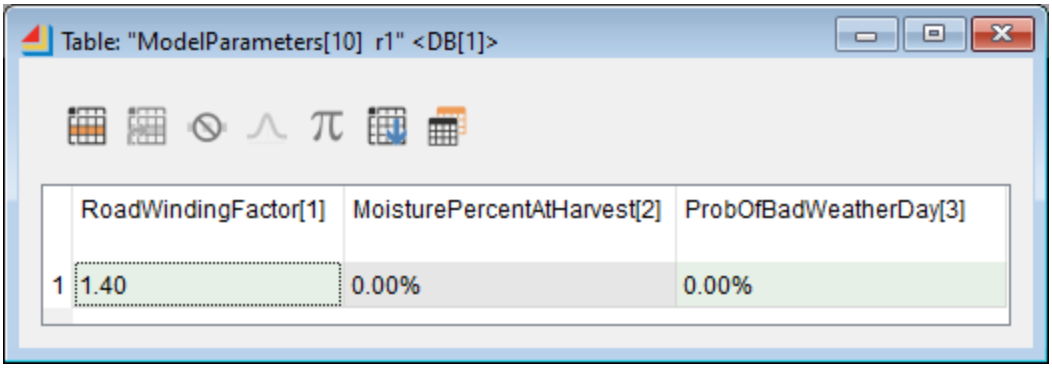


Figure 18. The *Model Parameters* table contains the *Probability of Bad Weather Day* field, which controls the proportion of bad weather days during harvest.

At the beginning of each day, a uniform random value between zero and one is generated and compared to the probability of bad weather day value to determine if the harvest crews can work that day. If today is a bad weather day, the harvest crews will not be permitted to operate on the field that day. It also increments the count of the number of bad weather days in the *Model Results* table.

The higher the probability of bad weather, the more harvestable days are reduced, which effectively requires the system to increase the quantity of harvest equipment needed to harvest the feedstock within the harvest window.

The *Model Options* table, shown in Figure 16, contains a boolean flag in the *Use Weather* field, which enables weather control. Setting this to true (1) will turn on the weather feature while setting this to false (0) will turn off the weather construct while retaining the probability data.

IBSAL 2.0 has also used historical weather data using Daymet (Thornton et al., 2020). When using historical data, precipitation thresholds must be set to determine harvestable and non-harvestable days.

5. RUNNING THE MODEL

5.1 GENERAL DISCUSSION ON RUNNING THE MODEL

The global time unit is set in the Simulation Setup dialog, shown in Figure 19, and must always remain in days. Many constructs in this model expect the global time unit to be days, and setting it to a different global time unit generates erroneous results.

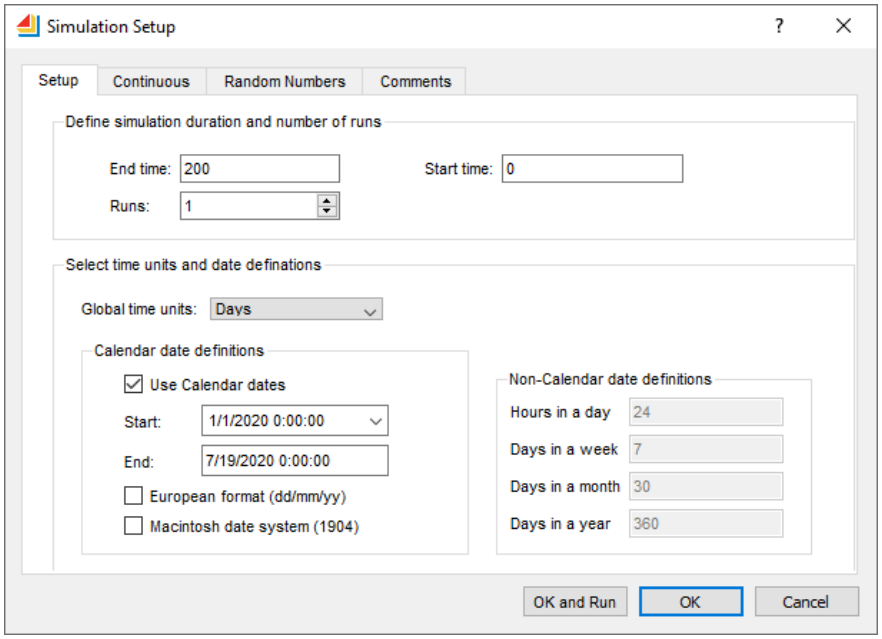


Figure 19. Simulation Setup dialog, which shows the global time units set to days.

The model's run length is also set in the Simulation Setup dialog. The run length can be modified, but we often run the model longer than the anticipated harvest window duration. If the harvest window is 120 days and we want to find the best crew configuration, setting the run length for an additional 20 to 50 percent longer is best. If, for example, we don't have enough crews to harvest within the harvest window, it's beneficial to know whether the harvest was completed on day 130 or day 170 to provide the necessary information about how many additional crews are needed.

As the model runs, the user can see the current simulation time in the lower left portion of the model. It is expressed in days because the model's default time unit is in days. As shown in Figure 20, the user can also see a clock with a rough estimate of the expected time to complete the model run, expressed in minutes. You will notice this clock runs faster and slower at times. For example, the clock tends to slow down during the season when lots of activity is happening for harvesting. The clock speeds up once the harvest is finished since only transport remains. So, the estimated time is affected by what occurs during the model run.

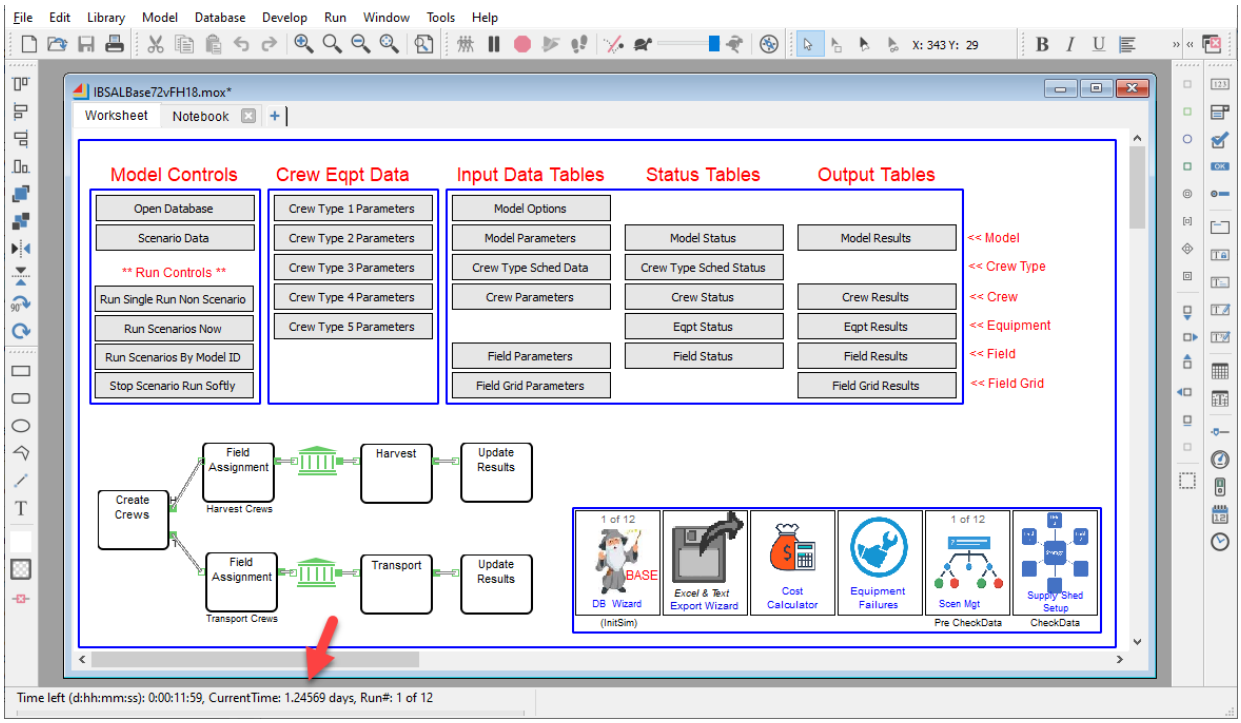


Figure 20. A screenshot of a model while running with the current simulation time is shown in the lower-left corner of the model.

The animation can be toggled on or off while running a model. If the animation is off, the model will run much faster. The user can see the crew and crew equipment items flowing through the system when the animation is on. It is sometimes helpful to slow the model down in this fashion to debug it during the run. Users may use the pause button on the Model toolbar if they want to pause a model during the run. Users can use the Pause block in the Utility library if they wish to pause a model at a specific time.

5.2 MANUAL MODEL RUNS

The IBSAL 2.0 model has been primarily set up to run scenarios using the Scenario Mgr block. However, a user can manually set up and run a model in the same manner as typical ExtendSim models. You can manually initiate the model run by clicking the Run Simulation button (green arrow) on the Model toolbar, as seen in Figure 21.

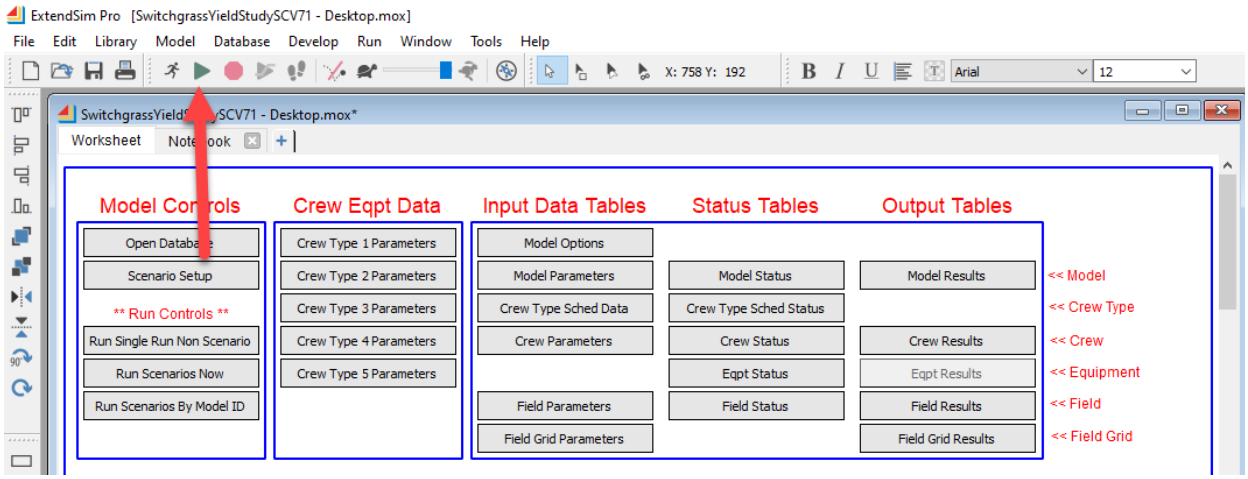


Figure 21. ExtendSim toolbar with the Run Model button identified by an arrow on the toolbar.

When the user wants to run the model manually, the number of replications may need to be adjusted. This can be done in the Simulation Setup dialog. The Simulation Setup dialog can be opened by navigating to the Run > Simulation Setup menu, as seen in Figure 22. The dialog item Runs sets the number of replications parameter.

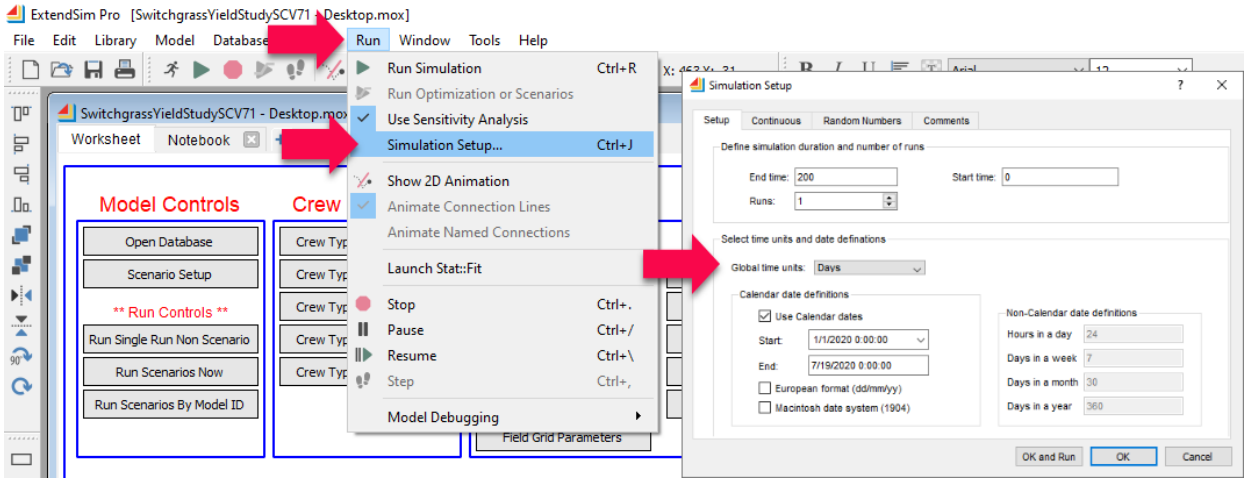


Figure 22. Steps to open the Simulation Setup dialog from the Run menu.

The output reports of a manually initiated run are captured like the output reports of a Scenario Mgr controlled run. The only difference is that no scenario information is displayed in the output reports; however, the date and time stamp are still recorded. The output reports are discussed further in Chapter 6.

5.3 SCENARIO RUNS

The Scenario Mgr block is typically used to run the model. Three buttons are used to run the scenarios, and they have been cloned out onto the model worksheet, as shown in Figure 21 in the leftmost column of buttons.

The first button, *Run Single Run Non-Scenario,* mimics the action of the green Run button on the toolbar as it does not use any data from the *Scenario Data* table.

The second button, *Run Scenarios Now*, will run all scenarios in the *Scenario Data* table with a true (1) value in the *Included* field and will use the *Num Replications* field to determine the number of replications to run each scenario.

The third button, *Run Scenarios by Model ID*, is similar to *the Run Scenarios Now* method in that it uses the *Included* and *Num Replications* fields, but it also considers the *Model ID* field. The model ID comes from the model name, which should be in the format "SomeModelName_123.mox". This method will use the number after the underscore as the model ID and run the scenarios with a matching model ID. This setup allows users to divide the scenarios to run simultaneously using multiple model instances.

The *Scenario Data* table is reevaluated at the beginning of each scenario run. The reevaluation allows the included scenarios and the number of replications to be modified during the study to reduce the experimentation time when the user can identify bad scenarios during the experiment.

6. OUTPUT REPORTS

6.1 PRIMARY OUTPUT REPORTS

The model produces several result tables. The critical model metrics are found in the *Model Results* table. The *Model Results* table contains one record per run, while each column reports an important model metric. The most important metrics include the amount harvested and transported and the cost per dry megagram. A detailed list of the metrics reported in the *Model Results* table is contained in Appendix B. This list also includes the field definitions of every table in the model.

The model also collects individual run results on the crews, crew equipment, and fields. These results are contained in the tables listed in Table 5. The crew results can be found in the *Crew Results* table. The *Crew Results* table includes one record per crew per model run. This table contains the days each crew worked, scheduled off, or couldn't work because of weather. This table also includes the total number of fields each crew processed and the amount of feedstock processed in units of dry megagrams.

Table 5. Primary result tables generated by the model

Table	Description
Model Results	Captures summary level model results and contains one record per model run.
Crew Results	Captures crew-related results and contains one record for each crew for each model run.
Crew Eqpt Results	Captures crew equipment-related results and contains one record for each crew equipment unit for each model run.
Field Results	Captures field-related results and contains one record for each field for each model run.

The *Crew Eqpt Results* table contains the equipment results with one record per equipment unit per run. This table includes the time each equipment unit spends on the field working, waiting on resources, traveling, and time in a down or failed state. This table contains the amount of fuel each unit required, the feedstock the equipment processed, and the overall cost per hour for the equipment.

The field results in the *Field Results* table contain one record per field per run. This table includes the size of each field, how much feedstock was processed by crew type, the crew ID by crew type, and the time completed by crew type. This table also contains the X and Y field coordinates and the distance to the refinery. This table also included additional field-related properties.

6.2 DEBUGGING LOGS

The user may include several log tables in the report, managing them in the *Model Options* table. Table 6 contains a list of log table options. These tables are explicitly used for model debugging. The log tables should not be turned on when running scenarios because they grow excessively and slow down the model. The tables should only be turned on when running single runs for the specific features that need debugging.

Table 6. Log options contained in the *Model Options* table

Log Option	Description
Capture Event Log	Captures various custom events from the model into the *Log Events* table. The user can set up the recording of special events by using additional options in the *Model Options* table. All event logging is disabled when the *Capture Event Log* field is unchecked.
Capture Event Log All Runs	Captures all events across all model runs when set to true (1). When set to false (0), only the last run's events are displayed in the table at the end of the run.
Capture Shift Info in Event Log	Captures all shift events.
Capture Can Travel Shift Info in Event Log	Captures all travel shift events.
Capture Weather Info in Event Log	Captures weather-related events.
Capture Crew Harvest Info in Event Log	Captures harvest crew events but not crew equipment events.
Capture Eqpt Harvest Info in Event Log	Captures harvest crew equipment events.
Capture Eqpt Failure Info in Event Log	Captures failure and repair events.
Capture Eqpt Transport Info in Event Log	Captures all transport crew events.

6.3 DATA EXPORT MGR

The Data Export Mgr block allows the user to quickly export selected output tables to a text file or Excel automatically. The Data Export Mgr block works with the *Table Export to Text* table in Figure 23 and the Table Export to Excel table in Figure 24. The benefit of using the Data Export Mgr block instead of the DB Import Export block is that this single block can export a list of tables.

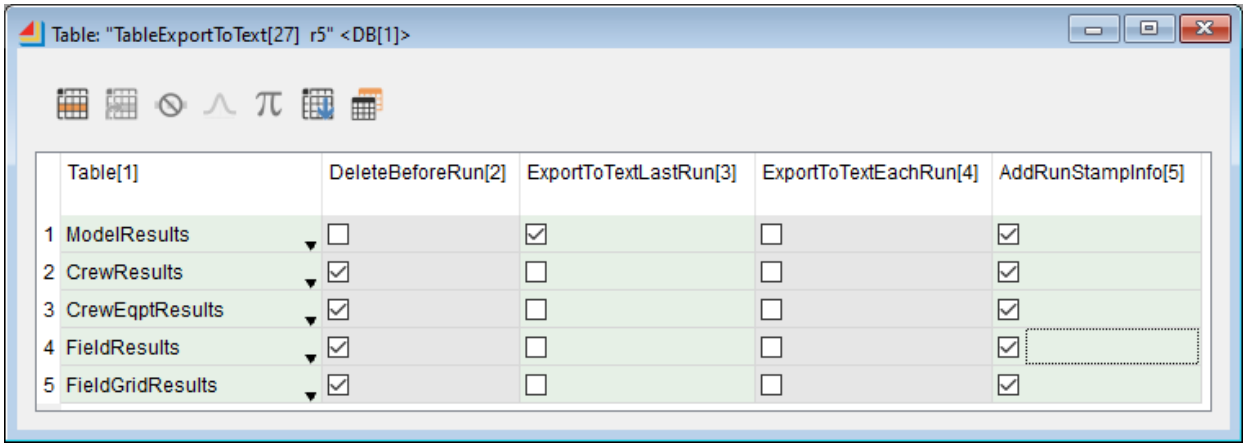
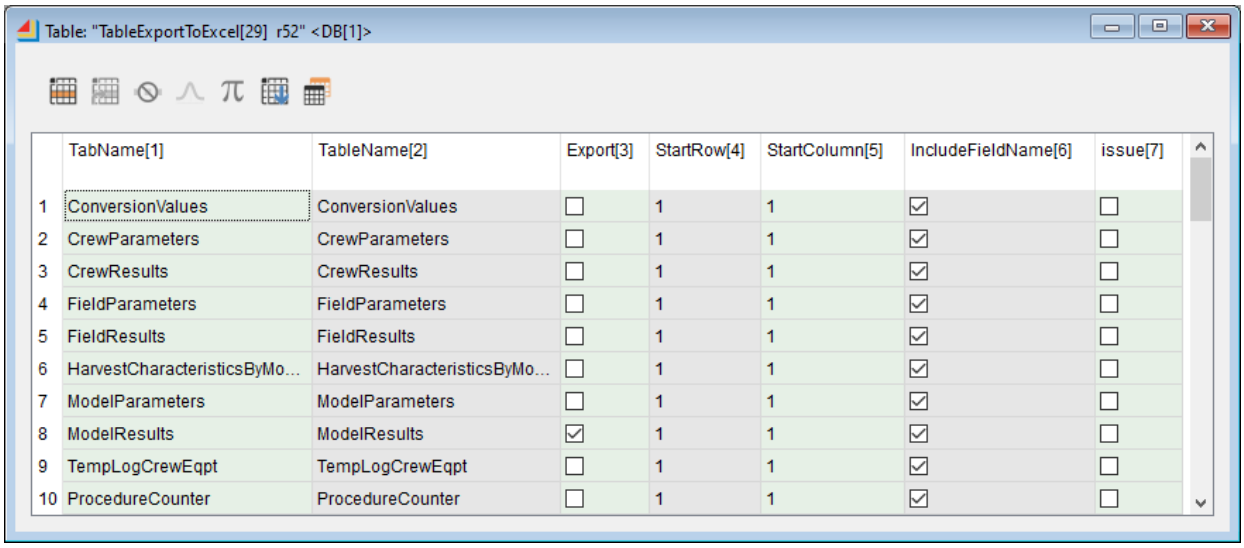


Figure 23. *Table Export to Text* table controls which tables will be exported at the end of the run.

The user may choose to add new tables to either list by using the Append New Records command and selecting which tables to add. Likewise, removing tables requires selecting the specific table and deleting the record.

When exporting to a text file, the Data Export Mgr block will prepend the model's file name to the beginning of the table name. For example, suppose the model's name is SWGv70.mox. In that case, the model results file will be named SWGv70ModelResults.txt, allowing models in the same folder to run simultaneously since each can export the *Model Results* table without a naming conflict. Because the model's name is unique, it results in a unique text file name. The user must be aware of several fields in the *Table Export to Text* table before setting up the text file export. These fields include the following:

- Delete Before Run – Some tables grow excessively large when experimenting because they record multiple data records per model run. If the user is not specifically interested in these tables, then the user should set this field to true (1), which will remove the results from the last run at the beginning of each run.
- Export to Text Last Run – Export to text on the last run.
- Export to Text Each Run – Export to text after each run. Each export will overwrite the last file. This option is helpful if the scenario runs are excessively long, and you still want to capture a partial set of output data even if the model crashes at some point during the run. For example, if the user runs the model for 1000 runs, exporting the Model Results table at the end of each run would be good because if the computer crashed after 500 runs, the text export would retain the result for half of the runs.
- Add Run Stamp Info – This option adds the model's name, run date and time, and scenario info (if running a scenario) to the selected result tables. The fields must be present for this option to work.



	TabName[1]	TableName[2]	Export[3]	StartRow[4]	StartColumn[5]	IncludeFieldName[6]	issue[7]
1	ConversionValues	ConversionValues	☐	1	1	☑	☐
2	CrewParameters	CrewParameters	☐	1	1	☑	☐
3	CrewResults	CrewResults	☐	1	1	☑	☐
4	FieldParameters	FieldParameters	☐	1	1	☑	☐
5	FieldResults	FieldResults	☐	1	1	☑	☐
6	HarvestCharacteristicsByMo...	HarvestCharacteristicsByMo...	☐	1	1	☑	☐
7	ModelParameters	ModelParameters	☐	1	1	☑	☐
8	ModelResults	ModelResults	☑	1	1	☑	☐
9	TempLogCrewEqpt	TempLogCrewEqpt	☐	1	1	☑	☐
10	ProcedureCounter	ProcedureCounter	☐	1	1	☑	☐

Figure 24. *Table Export to Excel* table allows users to automatically select the tables to export at the end of each run into Excel. The user can also indicate where the table is placed in the Excel workbook.

When exporting to an Excel file, the user must specify the Excel file name in the dialog box, shown in Figure 25. The file name can be anything but it must have the .xlsx extinction and already exist before the model runs. Although the file must already exist, it can be a blank spreadsheet. If this file is in a folder other than the model folder, the user must specify the path in the Data Export Mgr block dialog. Therefore, we recommend the Excel file remain in the same folder as the model, eliminating the need to qualify the path name when specifying the file name fully. The user must be aware of several fields in the *Table Export to Excel* table before setting up the Excel export. These fields include the following:

- Tab Name – Exports to this tab name in the spreadsheet.
- Table Name – Database table to export.
- Export – This option controls the data export for the table.
- Start Row – Specifies the starting row for the table.
- Start Column – Specifies the starting column for the table.
- Include Field Name – This option controls the export of the field names. If so, the field name goes into the row determined by the Start Row field.
- Issue – Rather than allowing user input, this option provides feedback to the user if a problem is encountered during the export.

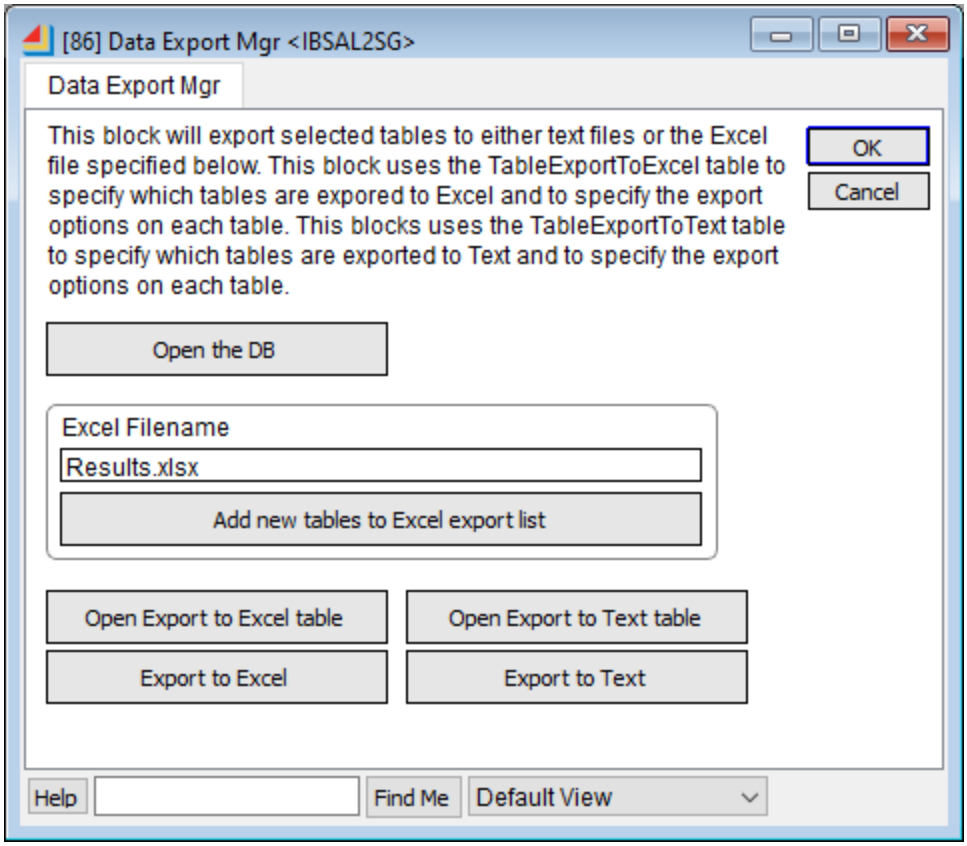


Figure 25. Data Export Mgr block dialog.

7. CONCLUSION

The redevelopment of IBSAL 2.0, focusing on integrating the internal ExtendSim database, has significantly streamlined the construction and simulation of feedstock models, enhancing ease and speed. Transitioning between different feedstocks within a supply shed model typically necessitates only modifications to the data, illustrating the system's efficiency. As a future enhancement, if the model were further decoupled from its data, monitoring changes to the model and feedstock data would become more straightforward. However, changes to the model's database structure would be necessary to address challenges with importing random distributions, as they can not be directly imported from a spreadsheet or text file in their current form.

8. REFERENCES

Diamond, Bob, David Krahl, Anthony Nastasi, and Peter Tag. “ExtendSim Advanced Techology: Integrated Simulation Database.” In Proceedings of the 2010 Winter Simulation Conference, 32–39. Baltimore, MD, USA: IEEE, 2010. https://doi.org/10.1109/WSC.2010.5679178.

ExtendSim. 2022. Users guide. Ver. 10.x Imagine That Inc., San Jose, CA.

Law, A. M. 2015. *Simulation Modeling and Analysis*, 5th ed. New York: McGraw-Hill.

Sokhansanj, Shahab, Erin Webb, and Anthony Turhollow. "Development of the Integrated Biomass Supply Analysis and Logistics Model (IBSAL)," June 1, 2008. https://doi.org/10.2172/932647.

Thornton, M.M., R. Shrestha, Y. Wei, P.E. Thornton, S. Kao, and B.E. Wilson. 2020. Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 4. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1840

Turhollow, Anthony, Erin Webb, and Shahab Sokhansanj. "Cost Methodology for Biomass Feedstocks: Herbaceous Crops and Agricultural Residues," December 1, 2009. https://doi.org/10.2172/969956

APPENDIX A. FILE SETUP

APPENDIX A. FILE SETUP

Table 7 contains the three files required to run the IBSAL 2.0 model and the appropriate storage location.

Table 7. Required files to run IBSAL 2.0

File	Description	Location
IBSALSC.mox	Model	Any location on PC or Server
IBSAL.lix	Library containing custom blocks.	Same location as the model
IBSAL.h	Include file with DB references for custom blocks.	ExtendSim/Extensions/Includes

The model file has a " mox " file extension and can be stored on your computer or a network drive folder. The model may be renamed to describe the study. You can adjust all parameters for the scenario as necessary through the database. Click the “Open Database” button on the main worksheet to modify the parameters. Once the parameters have been specified for the scenario, save the model or save the model as a new version if significant changes have been made.

The IBSAL library file has a file extension of “lix.” The IBSAL library contains the custom blocks used in the IBSAL 2.0 model. This file should be placed in the same folder as the model file. It could be placed in the ExtendSim\Library folder; however, the recommended location is in the same folder as the model file. The model automatically finds and opens the IBSAL Library if it’s in the ExtendSim library or the same folder as the model. However, please do not put the library file in both locations, as this typically leads to confusion about which file it’s using.

The IBSAL Include file has a file extension of “h.” The custom blocks in the model use the Include file to gain access to the database index numbers, including the database index, all table indexes, and all field indexes in the model. It must be placed in the ExtendSim\Extensions\Includes folder.

The Results spreadsheet has a file extension of “xlsx”, where you export the results. However, it doesn’t happen automatically. The user must initiate the export to Excel through the custom Data Export Mgr block. Because of this, the Results spreadsheet is optional until you initiate the export. The Results spreadsheet can be a blank Excel file, or it can be a preformatted Excel file. A preformatted Excel file could have charts already set up on various tables.

Although the Results spreadsheet can be placed anywhere on your computer, the recommended location is in the same folder as the model file. This location eliminates the need to manually specify the file path when the file is moved from one computer to another. The file can be named anything; however, if the name is changed, the new name must be recorded in the Data Export Mgr block.

APPENDIX B. DATABASE DOCUMENTATION

APPENDIX B. DATABASE DOCUMENTATION

Conversion Values

This table contains the constants for converting basic units within the model.

Hectare To Acre: The number of acres in one hectare.

Mg To Ton: The number of US tons in one megagram.

Hectare To M2: The number of square meters contained in one hectare.

Cost Data

This table contains the cost parameters for equipment. A crew type might need two or more records in this table if the equipment includes an implement—the *Crew Type X Eqpt Parameters* table and the Equipment Cost Calculator block reference this table.

Equipment Name: Name of the equipment, but this is only used for notation.

Horsepower Max: The maximum horsepower rating of the equipment. This is used for capability information.

Horsepower: The horsepower of the equipment used in the fuel calculation, which can be less than the maximum rated horsepower.

Fuel Consumption L Per Hour: The fuel consumption of the equipment.

List Price: The list price of the equipment. This is used to calculate the purchase price.

X Purchase Price: The original purchase price of the equipment, which is a percentage of the list price. The Eqpt Cost Calculator block calculates this field.

Salvage Value Coef 1: The salvage coefficient of the equipment. Please refer to the ORNL cost standards for this equipment.

Salvage Value Coef 2: The salvage coefficient of the equipment. Please refer to the ORNL cost standards for this equipment.

Salvage Value Coef 3: The salvage coefficient of the equipment. Please refer to the ORNL cost standards for this equipment.

X Salvage Factor: A general rule of thumb should be about 25% of new after five years. The Eqpt Cost Calculator block calculates this field.

X Salvage Value: This field shows the salvage value. The Eqpt Cost Calculator block calculates this field.

X Discounted Salvage Value: This field shows the discounted salvage value based on the salvage factors and coefficients. The Eqpt Cost Calculator block calculates this field.

Purchase Price Reference: This provides a space to list a reference for the equipment purchase price.

Labor Base Pay: This contains the base pay ($ per hour) for the labor that operates the equipment.

X Labor Cost Total Per Hour: Labor cost total per hour. This takes the labor cost and adds the benefit rate. The Eqpt Cost Calculator block calculates this field.

Labor Base Pay Reference: This provides a space to list a reference for the labor base pay.

Useful Life Hours: The ownership period or economic life of the asset.

Total Life RM Cost Fraction: The repair and maintenance cost as a percentage of the purchase cost.

M Annual Use Hours: The annual hours used for the equipment. This value comes from the model at the end of a run.

X Useful Life Years: Useful life of the equipment. This comes from the useful life (hours) and the annual hours used. The Eqpt Cost Calculator block calculates this field.

Useful Life Reference: This provides a space to list a reference for the useful life parameter.

X Capital Cost Total Per Hour: Capital cost per hour of use. The Eqpt Cost Calculator block calculates this field.

X Repair Maintenance Cost Total Per Hour: This contains the repair and maintenance cost per hour of use. The Eqpt Cost Calculator block calculates this field.

Repair Maintenance Reference: This provides a space to list a reference for the repair and maintenance.

X Fuel Usage Per Hour: The fuel usage per hour for the equipment. The units are gallons per hour. This is used as part of the cost-per-hour calculation. The Eqpt Cost Calculator block calculates this field.

Lube Factor: The Lube factor (% of fuel consumption).

X Fuel Lube Cost Total Per Hour: The fuel and lube cost per hour of use of the equipment. The Eqpt Cost Calculator block calculates this field.

X IHT Total Cost Per Hour: The costs from interest, housing, and taxes. The Eqpt Cost Calculator block calculates this field.

X Interest Cost Per Hour: The cost per hour of equipment related to Interest. The Eqpt Cost Calculator block calculates this field.

X Total Cost Per Hour: The total cost per hour of the equipment. The Eqpt Cost Calculator block calculates this field.

Cost Parameters

This table contains the cost parameters for the Equipment. The values should apply to all equipment.

Tax Rate: Tax rate as a percent of purchase price. The default value is 1% as per ASABE Standard. ASAE EP496.3 Feb 2006 (R2015) Cor 1.

Housing Rate: The housing rate as a percent of the purchase price. The default value is 0.75% as per ASABE Standard. ASAE EP496.3 Feb 2006 (R2015) Cor 1.

Insurance Rate: Insurance rate as a percent of purchase price. The default value is 025% as per ASABE Standard. ASAE EP496.3 Feb 2006 (R2015) Cor 1.

Benefit Rate: This contains the benefits / fringe benefits rate for the labor (% of base).

Benefit Rate Reference: This provides a space to list a reference for the benefit rate.

Interest Rate: This would be either a loan rate or the time value of money.

Diesel Off-Highway Cost per Gal: This provides the fuel cost for calculating costs. The units are ($ / gallon for off-highway diesel). This typically comes from https://www.eia.gov/petroleum/gasdiesel/. This is on the highway minus 18% for taxes.

Diesel On-Highway Cost per Gal: This provides the fuel cost for calculating costs. The units are ($ / gallon for on-highway diesel). This typically comes from https://www.eia.gov/petroleum/gasdiesel/

Gasoline Usage Factor: This provides the gasoline usage factor in units of gal/hp per hour. This comes from ASAE EP496.3 Feb 2006 (R2015) Cor 1.

Gasoline To Diesel Factor: This provides the gas to diesel factor. This comes from ASAE EP496.3 Feb 2006 (R2015) Cor 1.

Fuel Reference: This provides a space to list a reference for the fuel cost parameter.

Purchase Price to List Price Factor: The original purchase price to list price factor of the equipment.

Labor Hour Machine Hour Factor: The labor hour to machine hour factor.

Equipment Operating Time Factor: The equipment operating time factor.

Crew Eqpt Results

This table contains the equipment results for all crew equipment. This table is set up automatically at the beginning of the model run. There is one record for each crew equipment unit for each model run.

Model Name: The file name of the model.

CurrentSim: The run number from the CurrentSim variable.

Run Date Time: The date and time the model ran.

Scenario ID: The record number in the *Scenario Data* table. It will contain "-1" if the run is not a scenario.

Scenario Name: The scenario description in the *Scenario Data* table. It will be blank if the run is not a scenario.

Scenario Replication: The replication number of the scenario run. It will contain "-1" if the run is not a scenario.

Model ID: The model ID in the *Scenario Data* table when running an experiment using the *Scenario Data* table. It will contain "0" if the model ID does not control the run.

Eqpt ID: The equipment ID.

Crew ID: The crew ID.

Crew Type: The crew type. This is related to the type of work the crew does.

Processed Mg: The amount processed during the run by the crew equipment in units of megagrams.

Processed Mg Dry: The amount processed during the run by the crew equipment in units of dry megagrams.

Eqpt Yield Loss Mg: The dry matter loss due to the equipment.

Time Working Hours: The total time harvesting in the field by the harvesting equipment and loading and unloading by the transport equipment.

Time Traveling Hours: This is the time the harvesting equipment spent traveling to the fields and time traveling for the transport equipment.

Time Waiting on Resources Hours: The time in hours the equipment waits on other equipment.

Distance Traveled Km: The distance traveled in units of kilometers for the transport equipment.

Num Failure Events: The number of equipment failures during the run.

Time in Failed State Hours: The amount of time in hours the equipment spent in the failed state.

Num Loads: The number of loads the transport equipment hauled during the run.

Fuel Consumption L: This contains the total fuel consumption of equipment using the standard consumption formulas based on hours used and the usage rate. This includes the time the equipment is being repaired and waiting on other resources in the crew.

Cost per Hour: The cost per hour used to compute the total equipment cost.

Total Costs: The total costs for the equipment for the run.

Total Time Hours: This is the total time the crew equipment was operating to calculate the equipment cost. This includes working, traveling, waiting on resources, and being in a failed state.

Crew Eqpt Status

This table contains the status of the crew equipment. The data in this table is for the current run only. There is one record per crew equipment. This includes both harvest and transport equipment. This table is set up automatically at the beginning of each run by the DB Wizard block.

Eqpt ID: The equipment ID should correspond to the record number.

Crew ID: The crew ID.

Crew Type: The crew type. This is related to the kind of work the crew does.

Eqpt Results RIdx: This crew's record index in the *Crew Equipment Results* table.

Crew Results RIdx: This crew's record index for this specific run is in the *Crew Results* table.

Down: This field reports whether the equipment is in an operational state or a failed state. A true value (1) means the equipment has failed.

In TBF Q: This field will contain a true (1) value if the equipment is in an operational state and being used.

In TBF Waiting Q: This field will contain a true (1) value if the crew equipment is paused because it is off-shift or unused.

In TTR Q: This field will contain a true (1) value if the crew equipment is in a failed state.

In TTR Waiting Q: This field will contain a true (1) value if the crew equipment is paused because it is down but off shift.

TBF TTR Time Entered Q: The time the equipment failure item entered the queue (either the time between failures queue or time to repair queue).

TBF TTR Time of Last Event: The TBF or TTR status last update time. This is used to calculate the total time in the previous status.

TBF TTR Time Remaining: The time remaining on the TTR or TBF ticker.

TBF TTR Q Release Flag: This flag gets set to true (1) when the failure item needs to be released from its current TBF or TTR queue.

TBF TTR Waiting Q Release Flag: This flag gets set to true (1) when the failure item needs to be released from its current TBF or TTR waiting queue.

TBF TTR Pause: This flag gets set to true (1) when the crew item TBF or TTR time needs to be paused.

Crew Parameters

This table contains the parameters for the crews. Most of the parameters in this table relate to the quantity of crews and crew equipment created during the model run.

Num Crew Type 1: The number of crew items of type 1 created.

Num Eqpt per Crew Type 1: The number of crew equipment items in each crew type 1 unit.

Num Crew Type 2: The number of crew items of type 2 created.

Num Eqpt per Crew Type 2: The number of crew equipment items in each crew type 2 unit.

Num Crew Type 3: The number of crew items of type 3 created.

Num Eqpt per Crew Type 3: The number of crew equipment items in each crew type 3 unit.

Num Crew Type 4: The number of crew items of type 4 created.

Num Eqpt per Crew Type 4: The number of crew equipment items in each crew type 4 unit.

Num Crew Type 5: The number of crew items of type 5 created.

Num Eqpt per Crew Type 5: The number of crew equipment items in each crew type 5 unit.

Time Between Fields Hours: The average travel time in hours for the harvest crews to go from one field to another. This will be resampled for each crew traveling to a new field.

Crew Results

This table contains the crew results. This table is set up automatically at the beginning of the model run. There is one record for each crew for each model run.

Model Name: The file name of the model.

CurrentSim: The run number from the CurrentSim variable.

Run Date Time: The date and time the model ran.

Scenario ID: The record number in the *Scenario Data* table. It will contain "-1" if the run is not a scenario.

Scenario Name: The scenario description in the *Scenario Data* table. It will be blank if the run is not a scenario.

Scenario Replication: The replication number of the scenario run. It will contain "-1" if the run is not a scenario.

Model ID: The model ID in the *Scenario Data* table when running an experiment using the *Scenario Data* table. It will contain "0" if the model ID does not control the run.

Crew ID: The Crew ID.

Crew Type: The type of crew. This is related to the type of work the crew does.

Num Workdays but Rain: The number of days the crew is available, but the weather prevents it from working.

Num Workdays: The number of days the crew is available to work. This includes the workdays where harvesting cannot take place due to weather.

Scheduled off Days: This contains the number of scheduled off days if the crew works less than seven days a week.

Fields Processed: This contains the number of fields processed by the harvest crew or transported by the transport crew.

Processed Mg: The amount processed by the crew in units of megagrams. This includes moisture.

Processed Mg Dry: The amount of dry weight processed by the crew in units of megagrams.

Processed Ha: The amount harvested by the crew in units of hectares.

Eqpt Yield Loss Mg: The harvested feedstock loss due to the equipment. This is wet material.

Last Field Complete Time: The time this crew completed its previous field.

Fuel Consumption L: This contains the total fuel consumption of all crew equipment using the standard fuel consumption formula based on hours used and the horsepower of the equipment. This includes time the equipment is being repaired and waiting on other resources.

Total Costs: The total costs for the equipment in the crew for the run.

Total Time Hours: This is the total time in hours the crew was in a working state. This includes working, traveling, waiting on resources, and being in a failed state. This is used to calculate the cost of the crew.

Crew Status

This table contains the status of the crews. The data in this table is for the current run only. There is one record per crew. This table is set up automatically at the beginning of each run by the DB Wizard block.

Crew ID: This contains the Crew ID and should correspond to the record number.

Crew Type: The crew type. This is related to the type of work the crew does.

Field ID: This contains the field ID the crew is working on.

Done for Season: This field indicates that the crew is complete for the season.

Results RIdx: The crew's record index in the *Crew Results* table for this specific run.

Field Capacity Ha Hr: The speed of the equipment in hectares per hour. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

Material Capacity Mg Hr: The speed of the equipment in megagrams per hour. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

TBF Hours: The TBF parameter for the equipment. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

TTR Hours: The TTR parameter for the equipment. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

Yield Loss Percent: The percent of yield loss due to the equipment and is copied from the *Crew Type x Eqpt Parameters* table. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

Operational Width M: The operational width of the equipment in meters. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

Speed Km Hr: The speed of the equipment in km per hour. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

Operational Efficiency: The operational efficiency of the equipment while on the field. This data is copied from the *Crew Type x Eqpt Parameters* table at the beginning of each run by the DB Wizard.

Calculate Material Capacity: This Boolean should be set to true (1) if the material capacity of the equipment should be calculated using speed, width, yield, and operational efficiency.

Time Started on Field: This contains the time the crew arrived on the field. The units are in days.

Num Workdays but Rain: This is the number of working days that are not working due to weather while the equipment is on the field.

Num Workdays: This is the number of working days in the current field.

Scheduled Off-Days: This is the number of non-working days in their current field.

Num Trucks Loading: The number of trucks with feedstock loading at the field site.

Units in Use: The number of crew equipment operating on the field.

CrewType1EqptParameters, CrewType2EqptParameters, CrewType3EqptParameters, and CrewType4EqptParameters

This table contains the parameters for the crew type X equipment. This table has one record only and a field for each parameter.

Field Capacity Ha Hr: The speed of the equipment in hectares per hour. To NOT use this value, set this value to a negative value. This value will be resampled each hour and compared to the Material Capacity, and the slowest value will be used.

Material Capacity Mg Hr: The speed of the equipment in megagrams per hour. This assumes the material is wet. To Not use this value, set this value to a negative value. This value will be resampled each hour and compared to the Field Capacity, and the slowest value will be used.

TBF Hours: The operational time between failure events. This would be the uptime. This value will be resampled at the recovery point from a failure.

TTR Hours: The time the equipment should take to get repaired after a failure event. This only progresses during normal work hours. This value will be resampled for each failure event.

Fuel Consumption L per Hour: This equipment's fuel consumption in liters per hour.

Total Cost per Hour: This equipment’s total costs per hour, including labor costs. The Eqpt Cost Calculator block uses this value.

Equipment 1 Cost RIdx: The record number reference in the *Cost* table that this equipment corresponds to. The Eqpt Cost Calculator block uses this value.

Equipment 2 Cost RIdx: The record number reference in the *Cost* table that this equipment corresponds to. The Eqpt Cost Calculator block uses this value.

Equipment3CostRIdx: The record number reference in the *Cost* table that this equipment corresponds to. The Eqpt Cost Calculator block uses this value.

Yield Loss Percent: The percent of yield loss due to the equipment.

Operational Width M: The operational width of the equipment in units of meters. The operating efficiency of the equipment while on the field. This is only used when we calculate the capacity using speed, width, and yield.

Speed Km Hr: The speed of the equipment on the field in km per hour. This is only used when we calculate the capacity using speed, width, and yield.

Operational Efficiency: The operational efficiency of the equipment. This is only used when we calculate the capacity using speed, width, and yield.

Calculate Capacity: This Boolean should be set to true (1) if the capacity of the equipment should be calculated using speed, width, yield, and operational efficiency. This value will be compared to the field and material capacity, and the slowest value will be used.

Crew Type 5 Eqpt Parameters

This table contains the parameters for the crew type 5 equipment created and used in the model. This table has one record only and a field for each parameter.

Speed Highway Full Km Hr: The travel speed on the highway in kilometers/hour when the truck is full.

Speed Highway Empty Km Hr: The travel speed on the highway in kilometers/hour when the truck is empty.

Capacity per Load Mg: The capacity of the trucks per load in megagram, including moisture.

Num Loaders At Field Site: The number of loaders that will be available to load feedstock into the trucks at the field site (or depot if the model contains depots). If two or more loaders are used, only one truck will be loaded at a time, but it will be loaded faster.

Time to Unload Truck Minutes: The time in minutes to unload the truck at the refinery.

Time to Load Truck Minutes: The time in minutes to load the truck with feedstock at the field site.

TBF Hours: The operational time in hours between failure events. This would be the uptime.

TTR Hours: The time in hours the equipment should take to get repaired after a failure event. This only progresses during normal work hours.

Fuel Consumption L per Hour: This equipment's fuel consumption in liters per hour.

Total Cost Per Hour: Equipment costs per hour, including labor costs. The Eqpt Cost Calculator block uses this value.

Equipment 1 Cost RIdx: The record number reference in the *Cost* table that this equipment corresponds to. The Eqpt Cost Calculator block uses this value.

Equipment 2 Cost RIdx: The record number reference in the *Cost* table that this equipment corresponds to. The Eqpt Cost Calculator block uses this value.

Equipment 3 Cost RIdx: The record number reference in the *Cost* table that this equipment corresponds to. The Eqpt Cost Calculator block uses this value.

Crew Type Data

This table contains one record for each crew type. If the Use field is false (0), the crew type will be unused. This allows for less than the maximum crew types to be used in the model. This table contains one record per crew type.

Crew Type: The list of crew types.

Use: The crew type is not used if the Use field is false (0).

Crew Type Schedule Data

This table contains the crew schedules by crew type. This table has one record per crew type.

Crew Type: The list of crew types.

Working Days per Week: The number of working days per week for the crews of the specified crew type.

Working Hours per Day: The number of working hours per day for the crews of the specified crew type.

Stop Travel X Hours Before End of Shift: The number of hours before the end of the shift when traveling must stop. For transport crews, this is checked before departing the refinery. For harvest crews, this is checked before traveling to a new field.

Crew Type Schedule Status

This table contains the crew type schedule status. This table has one record per crew type.

Crew Type: The list of crew types.

Current Overall Availability: This includes weather for harvest crews. This does not include failures. With this set to false (0), a crew will not select a new field to process.

Current Working Status: The working status of the crew. This field is false (0) when the crew is off shift and true (1) when the crew is on shift.

Current Travel Status: The current travel status of the crew. This field is false (0) when the crew does not have enough time before the end of a shift to travel to the following field. With this set to false (0), a crew will not select a new field to process.

Next Time for Daily Shift On: The next time for the crew type's daily shift to turn on.

Next Time for Daily Shift Off: The next time for the crew type's daily shift to turn off.

Next Time for Weekly Shift On: The next time for the crew type's weekly shift to turn on.

Next Time for Weekly Shift Off: The next time for the crew type's weekly shift to turn off.

Next Time for Stop Travel On: The next time the crew type's travel shift turns on.

Done for Season: This field will get set to true (1) when the crew type is complete for the season.

Field Grid

This table contains one record for each field. Assume one farm will be placed every square km on a grid. The size and yield are variable. Distance to depot/refinery will be 40% more than by the crow flying. Not every field will be selected but it will be randomly chosen based on the percentage of land dedicated to the feedstock.

Field ID: This contains a generic identifier of the field.

X Location: This is the X Location on the grid where the field is located.

Y Location: This is the Y Location on the grid where the field is located.

Distance by Crow: This is the distance in kilometers to the refinery.

Distance by Road: This is the distance in kilometers to the refinery after applying the winding factor.

Probability: This field is a random value used to select fields randomly.

Field Grid Parameters

This table contains the field grid parameters used by the DB Wizard to set up the field grid. The scenario manager could replace some values in this table at the beginning of the run.

One Field per X Km 2: The field density for the supply shed.

Harvest Every X Years: The harvest frequency of the feedstock.

Distance Factor: This field contains a factor to represent the actual distance a vehicle will travel between the field and the refinery. This factor is multiplied by the straight-line distance between the field and the refinery.

Field Grid Results

This table contains the results of setting up the field grid. This table is set up automatically at the beginning of the model run.

Model Name: The file name of the model.

CurrentSim: The run number from the CurrentSim variable.

Run Date Time: The date and time the model ran.

Scenario ID: The record number in the *Scenario Data* table. It will contain "-1" if the run is not a scenario.

Scenario Name: The scenario description in the *Scenario Data* table. It will be blank if the run is not a scenario.

Scenario Replication: The replication number of the scenario run. It will contain "-1" if the run is not a scenario.

Model ID: The model ID in the *Scenario Data* table when running an experiment using the *Scenario Data* table. It will contain "0" if the model ID does not control the run.

OneFieldPerXKm2: This contains the field density for the supply shed.

Field Size: The average field size for the run that was used to set up the supply shed.

Yield: The average yield for the run that was used to set up the supply shed.

Num Fields Actual: The number of fields used to set up the supply shed annually.

Total Fields for X Years: The total fields needed in the supply shed, although not every field is harvested annually.

Pct of Landscape: The percent of the landscape in the supply shed that is used for the feedstock.

Target Annual Feedstock Mg: This is the feedstock needed in the supply shed. This is in a wet megagram. This is calculated by taking the number of fields * yield * field size.

Estimated Max Radius Km: This is the calculated maximum radius of the supply shed in units of kilometers.

Avg Distance to Field: This contains the average distance to the fields in the run (units of kilometers). This does not consider the winding factor.

Field Parameters

This table contains the field parameters. The scenario manager could replace some values in this table during the beginning of the run.

Num Fields: The number of fields the model will set up for the run. This value should not be a random distribution.

Field Size Ha: The desired field size in hectares. The field width will be calculated since the user sets the field size and length. If the field size is a random distribution, each field will resample its size from the distribution.

Yield Mg Ha: The yield of the field (megagrams per hectare). Each field will resample for its yield if this value is a random distribution. This includes moisture if the moisture percent is a positive value. This does not have non-harvestable mass.

Field Results

This table reports the results by field. This table is set up automatically at the beginning of the model run. There is one record for each field for each model run.

Model Name: The file name of the model.

CurrentSim: The run number from the CurrentSim variable.

Run Date Time: The date and time the model ran.

Scenario ID: The record number in the *Scenario Data* table. It will contain "-1" if the run is not a scenario.

Scenario Name: The scenario description in the *Scenario Data* table. It will be blank if the run is not a scenario.

Scenario Replication: The replication number of the scenario run. It will contain "-1" if the run is not a scenario.

Model ID: The model ID in the *Scenario Data* table when running an experiment using the *Scenario Data* table. It will contain "0" if the model ID does not control the run.

Field: This reports the Field ID.

Field Size M2: This reports the field size in square meters.

Field Size Mg: This reports the field's total mass, including moisture, in megagrams.

Field Size Mg Dry: This reports the total mass of the field in dry megagrams.

Field Size Ha: This reports the field size in hectares.

Field Size Ac: This reports the field size in acres.

Yield Mg Ha: This contains the field's yield (Mg per ha), including moisture.

X Location: This is the X coordinate of the field on the field grid.

Y Location: This is the Y coordinate of the field on the field grid.

Distance by Crow to Refinery: This is the direct distance in kilometers to the refinery.

Time Working on Field Hours: This contains the harvesters' total time to process the field. This is for all harvesting processes. The time units are in hours.

Distance by Road to Refinery: This is the distance in kilometers to the refinery after applying the winding factor.

Eqpt Yield Loss Mg: The harvested feedstock loss due to the equipment.

CrwTp1CrewID: The crew ID (crew type 1) that processed the field.

CrwTp1ProcessedMg: This contains the amount, including moisture, that crew type 1 processed in megagrams.

CrwTp1ProcessedMgDry: This contains the amount crew type 1 processed in dry megagrams.

Crew Type 1 Time Started: This contains the time in days crew type 1 started processing the field.

Crew Type 1 Time Completed: The time crew type 1 completed processing the field. The time units are in days.

Crew Type 2 Crew ID: The crew ID (crew type 2) that processed the field.

Crew Type 2 Processed Mg: This contains the amount, including moisture, crew type 2 processed in megagrams.

Crew Type 2 Processed Mg Dry: This contains the amount that crew type 2 processed in dry megagrams.

Crew Type 2 Time Started: This contains the time in days crew type 2 started processing the field.

Crew Type 2 Time Completed: This contains the time crew type 2 completed processing the field. The time units are in days.

Crew Type 3 Crew ID: The crew ID (crew type 3) that processed the field.

Crew Type 3 Processed Mg: This contains the amount, including moisture, that crew type 3 processed in megagrams.

Crew Type 3 Processed Mg Dry: This contains the amount that crew type 3 processed in dry megagrams.

Crew Type 3 Time Started: This contains the time crew type 3 started processing the field. The time units are in days.

Crew Type 3 Time Completed: This contains the time crew type 3 completed processing the field. The time units are in days.

Crew Type 4 Crew ID: The crew ID (crew type 4) that processed the field.

Crew Type 4 Processed Mg: This contains the amount, including moisture, that crew type 4 processed in megagrams.

Crew Type 4 Processed Mg Dry: This contains the amount that crew type 4 processed in dry megagrams.

Crew Type 4 Time Started: This contains the time crew type 4 started processing the field. The time units are in days.

Crew Type 4 Time Completed: This contains the time crew type 4 completed processing the field. The time units are in days.

Crew Type 5 Crew ID: The crew ID (crew type 5) that processed the field.

Crew Type 5ProcessedMg: This contains the amount, including moisture, that crew type 5 processed in megagrams.

Crew Type 5 Processed Mg Dry: This contains the amount that crew type 5 processed in dry megagrams.

Crew Type 5 Time Started: This contains the time crew type 5 started processing the field. The time units are in days.

Crew Type 5 Time Completed: This contains the time crew type 5 completed processing the field. The time units are in days.

Yield Loss Mg: The eqpt yield loss in megagrams, including moisture.

Mark for Deletion: This field will get marked at the end of the model run if the field has not been harvested to trim the length of the *Field Results* table.

Moisture Pct: The overall moisture percentage of the field. This becomes useful if the moisture percent is a random distribution.

Field Status

This table contains the temporary field status data. The data in this table is for the current run only. This table has one record per field.

Field: This contains the Field ID.

Results RIdx: The record index in the *Field Results* table for this field for this run.

Crew Type Needed: The following crew type is needed for this field.

Crew ID Assigned: The current Crew ID assigned to the field.

Amt to Process Mg: This contains the feedstock yet to be processed on the field by the current crew type and is reset after each crew type completes its task.

Amt Processed Mg: This contains the feedstock processed on the field by the current crew type and is reset after each crew type completes its task.

Crew Type 1 Done: This contains a Boolean field set to true (1) when crew type 1 completes the field.

Crew Type 2 Done: This contains a Boolean field set to true (1) when crew type 2 completes the field.

Crew Type 3 Done: This contains a Boolean field set to true (1) when crew type 3 completes the field.

Crew Type 4 Done: This contains a Boolean field set to true (1) when crew type 4 completes the field.

Crew Type 5 Done: This contains a Boolean field set to true (1) when crew type 5 completes the field.

List Crew Types

This table contains the unique list of crew types. The crew types can be renamed in this table.

Name: The unique list of crew types.

List Events

This table contains the unique list of events for the *Log Events* table.

Name: The unique list of events for the *Log Events* table.

List Log Event Type

This table contains the unique list of events for the *Temp Log Crew Eqpt* table.

Name: The unique list of events for the *Temp Log Crew Eqpt* table.

List Yes No

This table contains the list of Yes / No. This is used in various options in the model.

Name: List of Yes / No options.

Log Events

This table contains a log of events during the model run—the *Model Options* table controls which events are logged.

Run ID: The run number of the event.

Event ID: The Event ID or a fixed record number.

Crew ID: This field identifies the crew ID.

Eqpt ID: This field identifies the equipment ID.

Crew Type: This field identifies the crew type.

Field ID: The field related to the event.

Date and Time: The time the event occurred.

Time: The time the event occurred.

Event Type: The event type.

Value 1: This field contains a value related to the event type; each could have a different meaning.

Value 2: This field contains a value related to the event type; each could have a different meaning.

Value 3: This field contains a value related to the event type; each could have a different meaning.

Model Options

This table contains various model options. This table contains one field for each option.

Use Down Events: If this field is false (0), the model ignores the down events. If this field is set to yes, then this model applies the TBF and TTR on the crew equipment.

Use Weather: If the Boolean is true (1), this option enables the weather events. Otherwise, all working days will be harvestable days.

Use Cost Calculator: This option enables the Eqpt Cost Calculator block to calculate the cost per hour for each piece of equipment. Otherwise, the model uses the fixed cost per hour in the *Crew Type Eqpt Parameters* table.

Use Transport Crews: This field enables transport crews to transport feedstock to the refinery. Otherwise, only the harvest crews are created.

Use Optimization Block: This option enables the Scenario Mgr block.

Run Length: The run length of the simulation and the units are in days. The DB Wizard block will set the run length at the beginning of each run.

Capture Event Log: This option controls the capture of the event log.

Capture Event Log All Runs: This option keeps or removes events from past replications. If it is off, only the events from the last run are reported.

Capture Shift Info in Event Log: This option controls the capture of the shift if the option to capture the log events is on.

Capture Can Travel Shift Info in Event Log: This option controls the capture of the travel shift events if the option to capture the log events is on.

Capture Weather Info in Event Log: This option controls the capture of the weather events if the option to capture the log events is on.

Capture Crew Harvest Info in Event Log: This option controls the capture of the harvest “crew” events if the option to capture the log events is on.

Capture Eqpt Harvest Info in Event Log: This option controls the capture of the harvest “equipment” events if the option to capture the log events is on.

Capture Eqpt Failure Info in Event Log: This option controls the capture of failure events if the option to capture the log events is on.

Capture Eqpt Transport Info in Event Log: This option controls the capture of the transport equipment events if the option to capture the log events is on.

Animation Option: This option controls the animation level of the model.

Model Parameters

This table contains various model parameters. This table contains one field for each parameter. The scenario manager could replace some values in this table at the beginning of the run.

Road Winding Factor: The road winding factor inflates the transport distance to represent the travel distance better.

Moisture Percent at Harvest: The moisture percentage of the crop as it is harvested.

Prob of Bad Weather Day: The probability of a rainy day, which prevents harvesters from working in the field.

Model Results

This table captures various model results. This table contains one record per model run.

Model Name: The file name of the model.

CurrentSim: The run number from the CurrentSim variable.

Run Date Time: The date and time the model ran.

Scenario ID: The record number in the *Scenario Data* table. It will contain “-1” if the run is not a scenario.

Scenario Name: The scenario description in the *Scenario Data* table. It will be blank if the run is not a scenario.

Scenario Replication: The replication number of the scenario run. It will contain “-1” if the run is not a scenario.

Model ID: The model ID in the *Scenario Data* table when running an experiment using the *Scenario Data* table. It will contain “0” if the model ID does not control the run.

Yield: This contains the average yield of the fields in megagrams per hectare.

Num Fields Available: The number of available fields in the model run.

Num Crew Type 1: This field reports the number of crews of type 1 in the model run.

Num Eqpt per Crew Type 1: This field captures the number of equipment per crew of type 1 in the model run.

Num Crew Type 2: This field captures the number of crews of type 2 in the model run.

Num Eqpt per Crew Type 2: This field captures the number of equipment per crew of type 2 in the model run.

Num Crew Type 3: This field captures the number of crews of type 3 in the model run.

Num Eqpt per Crew Type 3: This field captures the number of equipment per crew of type 3 in the model run.

Num Crew Type 4: This field captures the number of crews of type 4 in the model run.

Num Eqpt per Crew Type 4: This field captures the number of equipment per crew of type 4 in the model run.

Num Crew Type 5: This field captures the number of crews of type 5 set up in the model run in the model run.

Num Eqpt per Crew Type 5: This field captures the number of equipment per crew of type 5 in the model run.

Run Length: This field captures the run length of the model, which is an input.

Prob of Bad Weather Day: This field captures the probability of a bad weather day, which is an input.

Yield Option: This field reports the yield set up for the model run.

Harvested Mg: The amount harvested for the run. This includes moisture. The units are in megagrams.

Harvested Fields: This field captures the number of fields completely harvested during the model run.

Harvested Mg Dry: The amount harvested for the run. This does not include moisture. The units are in Mg.

Harvested Ha: The area harvested for the run. The units are in hectares.

Eqpt Yield Loss Mg: The harvested feedstock loss due to the equipment. This is wet material.

Num Good Weather Days: The number of days the harvest equipment is available to work with acceptable weather. This does not count good weather days when the crews are not working.

Num Bad Weather Days: The number of days the harvest equipment is available to work, but the weather prevents it from working. This does not count bad weather days when the crews are not working.

Total Harvesting Costs: The total costs for all harvesting crews for the run.

Harvesting Cost Per Mg Dry: The total harvesting cost per dry megagrams.

Num Failure Events: The number of failure events the equipment has had during the run.

Total Time in Failed State Hours: The time the equipment is in the failed state. The units are in hours.

Fuel Consumption L: This contains the total fuel consumption of all equipment in this run.

Num Loads Trucks: The number of loads the trucks hauled.

Amount Not Transported Mg: The amount of feedstock not transported off the field. This could have been feedstock not harvested or harvested but not transported.

Transported Mg: The total feedstock transported to the refinery in wet megagrams.

Transported Mg Dry: The total feedstock transported to the refinery in dry megagrams.

Total Transport Costs: The total transportation cost for the feedstock.

Total Transport Distance: The total km traveled to transport the feedstock from the field to the refinery.

Transport Cost per Mg Dry: The transportation cost per dry megagram for the feedstock.

Total Cost per Mg Dry: The feedstock harvest and transport cost per dry megagram.

Num Transport Crews: The number of transport crews.

Num Trucks per Crew: The number of trucks in each transport crew.

Pct of Landscape: The percent of the landscape in the supply shed used for fields.

One Field per X Km 2: The grid size in square kilometers to place a field.

Estimated Max Radius Km: This contains the maximum radius required for the supply shed. The units are in kilometers. This is capturing one of the primary model inputs.

Total Fields for X Years: This contains the required fields, considering every field might not be harvested yearly. The model only creates the fields to be harvested this year.

Avg Distance to Field: This contains the average distance to the fields in this model run. This should roughly be 2/3 * radius of the supply shed. The units are in kilometers.

Crew Type 1 Day Complete: The day crew type 1 completed all fields.

Crew Type 2 Day Complete: The day crew type 2 completed all fields.

Crew Type 3 Day Complete: The day crew type 3 completed all fields.

Crew Type 4 Day Complete: The day crew type 4 completed all fields.

Crew Type 5 Day Complete: The day crew type 5 completed all fields.

Crew Type 1 Total Time Hours: This is the total time the crew type 1 was in a working state. This includes the time working, traveling, waiting on resources, and being in a failed state. This value is used to calculate the cost of the crew.

Crew Type 2 Total Time Hours: This is the total time the crew type 2 was in a working state. This includes the time working, traveling, waiting on resources, and being in a failed state. This value is used to calculate the cost of the crew.

Crew Type 3 Total Time Hours: This is the total time the crew type 3 was in a working state. This includes the time working, traveling, waiting on resources, and being in a failed state. This value is used to calculate the cost of the crew.

Crew Type 4 Total Time Hours: This is the total time the crew type 4 was in a working state. This includes the time working, traveling, waiting on resources, and being in a failed state. This value is used to calculate the cost of the crew.

Crew Type 5 Total Time Hours: This is the total time the crew type 5 was in a working state. This includes the time working, traveling, waiting on resources, and being in a failed state. This value is used to calculate the cost of the crew.

Crew Type 1 Total Cost: This field reports the total cost of crew type 1.

Crew Type 2 Total Cost: This field reports the total cost of crew type 2.

Crew Type 3 Total Cost: This field reports the total cost of crew type 3.

Crew Type 4 Total Cost: This field reports the total cost of crew type 4.

Crew Type 5 Total Cost: This field reports the total cost of crew type 5.

Crew Type 1 Fuel Consumption L: This field reports the total fuel consumed for all crews of type 1.

Crew Type 2 Fuel Consumption L: This field reports the total fuel consumed for all crews of type 2.

Crew Type 3 Fuel Consumption L: This field reports the total fuel consumed for all crews of type 3.

Crew Type 4 Fuel Consumption L: This field reports the total fuel consumed for all crews of type 4.

Crew Type 5 Fuel Consumption L: This field reports the total fuel consumed for all crews of type 5.

Model Status

This table contains the status of various aspects of the model. The data in this table is for the current run only. This table has only one record and a field for each property it monitors.

Bad Weather Day: The current weather status. 0 is a harvestable day, and 1 is a non-harvestable day.

Done for Season Harvest: This indicates that all fields are complete for the season. False (0) is not done, and true (1) is done.

Done for Season Transport: This field will be set to 1 when the transportation process is complete for the season.

Log File ID: The log file ID for exporting errors during the run. This is a model developer feature.

Scenario Data

This table contains the scenarios that will run when either the "Run Scenarios by Model ID" or "Run Scenario Now" buttons on the main model worksheet are used to run the model. Many fields listed in this table change depending on the specifics of the study.

Scenario Description: This contains a short description of the scenario.

Include: This field contains a Boolean flag. If the Boolean flag is true (1), this scenario will be included in the next set of scenario runs.

Num Replications: The number of replications for the specified scenario. This value can be modified after the scenario runs have been initiated.

Current Replication: The number of replications that have been run of the specified scenario during the experiment.

Model ID: The model ID. This will be used to compare against the portion of the model's name after an underscore. If the run option "Run Scenarios by Model ID" is chosen, only the records with the matching model ID will run in the experiment.

Table Export to Excel

This table contains the tables to be exported to Excel using the Data Export Mgr block. The file name and location are specified in the Data Export Mgr dialog.

Tab Name: The tab name that the table will be exported to. If the tab name does not exist, then the tab will get created automatically. Please keep tab names short.

Table Name: The table name that is to be exported to Excel.

Export: This field contains a Boolean checkbox that controls the table export. The table will only be exported if the value is true (1).

Start Row: The starting row or row offset in Excel when exporting data.

Start Column: The starting column or offset in Excel when exporting data.

Include Field Name: This field contains a Boolean checkbox controlling the export of the field name. The field name will only be exported if the value is true (1).

Issue: This field contains a Boolean checkbox that the Data Export Mgr will check if it detects an error when exporting the table.

Table Export to Text

This table contains the list of result tables that could potentially be manipulated in some fashion by the DB Wizard at the end of each run and exported to a text file if the export Boolean is selected. Table: The table name.

Delete Before Run: This table will be deleted at the start of the run if the Boolean check box is selected.

Export to Text Last Run: This table will be exported to a text file at the end of the last run if the Boolean check box is selected.

Export to Text Each Run: This table will be exported to a text file at the end of every run if the Boolean check box is selected.

Add Run Stamp Info: This table will get the run information and time stamp to each record associated with the current run if the Boolean check box is selected.

Weather Current Year

This table contains the weather data applied during the current simulation year.

Year: The weather year.

Year Day: The day of the year.

Precipitation MM: The amount of precipitation for the day in units of millimeters.

Temp Max C: The maximum temperature for the day in Celsius.

Temp Min C: The minimum temperature for the day in Celsius.

City: The city information where the current weather data comes from.

APPENDIX C. ATTRIBUTE LIST

APPENDIX C. ATTRIBUTE DOCUMENTATION

aAmountMg – This attribute contains the amount of feedstock processed for the set chunk of time in **wet feedstock** mass and applies to both harvest crew equipment and transport crew equipment. The harvest crew equipment contains the amount the equipment will process that hour. For the transport crew equipment, it includes the amount of feedstock loaded on the truck.

aAmountMgDry – This attribute contains the amount of feedstock processed for the set chunk of time in **dry feedstock** mass and applies to both harvest crew equipment and transport crew equipment. The harvest crew equipment contains the amount the equipment will process that hour. For the transport crew equipment, it includes the amount of feedstock loaded on the truck.

aComplete – This attribute applies to harvest crew equipment items only. During the equipment harvest loop, the attribute is set to 1 when the field is complete, so the crew equipment item will not return to the loop to harvest the same field the next hour.

aCrwID – This attribute contains the unique crew ID on the crew and crew equipment items for both harvest and transport crews. The attribute also points to the record index of the crew in the *Crew Status* table but not the *Crew Results* table.

aCrwRsltsRIdx – This attribute contains the record index of the crew to the *Crew Results* table. It is valid on the crew and the crew equipment items and for harvest and transport crews.

aCrwTmCmplt – The harvest crew item uses this attribute. It is set to the current simulation time when all the harvest crew equipment items are finished with the field and batched back into the crew item.

aCrwTmStart – The harvest crew item uses this attribute. It is set to the current simulation time when the harvest crew item arrives at the field to begin harvesting.

aCrwType – This attribute contains the crew type and applies to the crew and crew equipment items for harvest and transport crews.

aDelayTime – This is a generic attribute containing the remaining time an item should be held in an Activity or Queue Equation block. All items use this attribute.

aDelayTimeOrig – The transport crew equipment items use this attribute. It contains the original time the item should be held in an Activity or Queue Equation block.

aDepartureTime – The attribute contains the time the transport task will be completed and is used by the transport crew equipment items. It is set before the equipment starts the transport task and is used in the Queue Quation and Activity blocks so it can release the item at the appropriate time.

aDistance – This attribute contains the distance from the refinery to the field and is used by the transport crew equipment items.

AEqptID – This attribute contains the unique crew equipment ID of the item and is only valid on the crew equipment items. It points to the record index of the crew equipment in the *Crew Equipment Status* table but not the *Crew Equipment Results* table.

aEqptRsltsRIdx – This attribute contains the record index of the crew equipment in the *Crew Equipment Results* table. It is only valid on the crew equipment items for harvest and transport crews.

aFldID – This attribute contains the record index of the field in the *Field Status* table to which the crew is assigned. It is valid on both the crew and crew equipment items for harvest and transport crews.

aFldRsltsRIdx – This attribute contains the record index of the field to which the crew is assigned in the *Field Results* table. It is valid on both the crew and crew equipment items, and it applies to both harvest and transport crews.

aNumInCrew – This attribute contains the number of crew equipment items included in the crew item. It is set on the harvest and transport crew item when it is initialized and is used to split it into the specified number of crew equipment items.

aPath – This attribute contains the path the item should take when passing through a Select Item Out block.

aRunID – This attribute contains the run ID of the simulation. All items use this attribute for writing results to log tables.

aTBFHours – This is used in the equipment failure construct. The attribute contains the equipment's on-shift time to remain running until it hits its next failure event.

aTimeEntered – This attribute is used by all items to log various events. This attribute contains the time an item enters an Activity or Queue Equation block.

aTimeExited – This attribute is used by all items to log various events. This attribute contains the time an item exits an Activity or Queue Equation block.

aTTRHours – This is used in the equipment failure construct. It contains the on-shift time required to repair the equipment failure.

aUnused – This attribute is only used as a placeholder in equation blocks.

aYieldMgHa – This attribute contains the field yield. It is set on the crew item after it is assigned a field. The attribute is set only once per field and used to calculate the harvesting crew equipment item's material and field capacity.

aYldLossMg – This attribute contains the yield loss from harvesting for the harvest crew equipment items. The value is recalculated on each in-field harvest loop.