
Computer Simulation of Discrete Flows

1.1. Introduction

The simulation of computerized flows gained its reputation with the development of the field of logistics and as a result of the computational power now available on personal computers.

All types of flows can be modeled, whether they are discrete or continuous, and many businesses use simulation tools instead of physical systems or prototypes and the inevitable costs they entail.

This is not to say that the software market has abundant applications, in fact there are relatively few, but the editors have built up considerable experience over the past few years and can suggest uses covering most sectors (see section 10.4 of Volume 1).

Historically, the first pieces of simulation software appeared in the 1990s (Scitor Process, ExtendSim, etc). At that time, the computing power that was available limited the capability of the software, and their usability was far from convincing.

The main body of this chapter deals with a non-industrial example, chosen intentionally to demonstrate that logistics and the simulation of flows can also be applied in more unusual sectors.

1.2. Worked example

In order to give a glimpse of the range of possibilities covered by computerized flow management, in particular with the ExtendSim 9 software, we will create a simulation modeling the small French winter sports resort 'Levant', with its skiers, ski lifts and pistes.

COMMENT 1.1.–

– The ExtendSim 9 software has been chosen because this is what I teach to my students in the ‘Logistics and Transport Management’ department at the University of Burgundy – Faculty of Science & Technology and Institute of Technology Chalon-sur-Saône.

– A usable version of the software is available on the publisher’s Website (see the Internet links at the end of the book).

– We thank 1point2, the official distributor of the ExtendSim software in France, for providing us with a US version.

1.2.1. Map of the resort

Figure 1.1 shows a map of the whole ski resort, with its pistes and ski lifts.

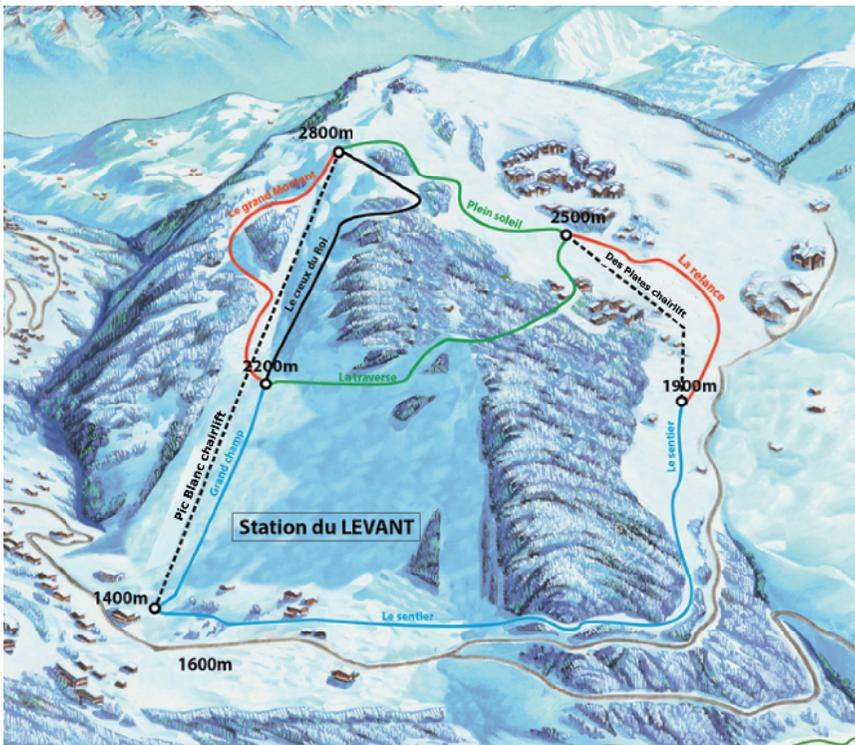


Figure 1.1. Map of the ‘Levant’ ski resort. For a color version of this figure, see www.iste.co.uk/reveillac/modeling3.zip

1.2.2. Problem statement and design brief

The full specifications to be incorporated are as follows:

- Resort opening times: 9:00 am–5:30 pm.
- Arrival frequency of skiers at the ski lifts, in seconds:
 - 9:00 am–10:30 am: mean = 5 s, standard deviation = 1.5 s;
 - 10:30 am–12:30 pm: mean = 14 s, standard deviation = 6 s;
 - 12:30 pm–1:45 pm: mean = 9 s, standard deviation = 4s;
 - 1:45 pm–2:30 pm: mean = 14 s, standard deviation = 6 s;
 - 2:30 pm–5:30 pm: mean = 20 s, standard deviation = 7.5 s.
- Ski lift specifications:
 - ‘Pic Blanc’ chairlift:
 - capacity per chair: 4 skiers;
 - lift duration: 9 min;
 - frequency of chair arrival: 18 s;
 - personnel: 1 operator.
 - ‘Plates’ chairlift:
 - capacity per chair: 3 skiers;
 - lift duration: 6 min;
 - frequency of chair arrival: 15 s;
 - personnel: 1 operator.
- Workforce required:
 - two operators (1 per chairlift) who work from 9:00 am to 5:30 pm;
 - hourly cost of 1 operator: \$18.25/h.
- Skier descent time by piste:
 - ‘Grand champ’: mean = 5 min, standard deviation = 2.5 min;
 - ‘La traverse’: mean = 9 min, standard deviation = 3.5 min;
 - ‘Le creux du Roi’: mean = 6 min, standard deviation = 2.5 min;
 - ‘Le grand Montant’: mean = 7 min, standard deviation = 2 min;
 - ‘Plein soleil’: mean = 6 min, standard deviation = 1.5 min;

- 'Le sentier': mean = 11 min, standard deviation = 3 min;
- 'La relance': mean = 6.5 min, standard deviation = 1.75 min.

– The probabilities of the different choices skiers make at each decision point are as follows:

- upon arrival at the resort:
 - take the 'Pic blanc' chairlift: 64%;
 - take the 'Plates' chairlift: 36%.
- upon arrival at the foot of the 'Grand champ' and 'Le sentier' pistes:
 - head toward the start of the 'Pic blanc' chairlift: 88%;
 - head toward the parking lot (leave the slopes): 12%.
- upon arrival at the foot of the 'La relance' piste:
 - head toward the 'Le sentier' piste: 60%;
 - head toward the 'Plates' chairlift: 28%;
 - head toward the car-park: 12%.
- upon arrival at the top of the 'Pic blanc' chairlift:
 - head toward the 'Le grand Montant' piste: 35%;
 - head toward 'Le creux du Roi' piste: 20%;
 - head toward the 'Grand soleil' piste: 45%.
- upon arrival at the top of the 'Des Plates' chairlift:
 - head toward the 'La traverse' piste: 62%;
 - head toward the 'La relance' piste: 38%.
- at the foot of the 'Plein soleil' piste:
 - head toward the 'La traverse' piste: 56%;
 - head toward the 'La relance' piste: 44%.
- Assorted constraints and observations:

- evidently, the pistes shown on the map are for descent only, the skiers do not climb up the slopes. The altitudes displayed on the map indicate the direction of descent;

- skiers can reach both chairlifts by road and arrive with a vehicle. A parking lot is available in front of each chairlift;

- when a skier arrives at the foot of the 'Grand champ' and 'Le sentier' pistes, they can decide to stop skiing and return to their vehicle, situated in the 'Pic blanc' parking lot. This is also the case at the foot of the 'La relance' piste, where the skier can return to the 'Plates' parking lot;

- skiers can return to the ‘Plates’ chairlift by taking the ‘Pic blanc’ chairlift and then descending the ‘Plein soleil’ and ‘La relance’ pistes;

- ski passes are given to the skiers in the form of a swipe card which they wear around their necks;

- to access the chairlifts, the skiers must present their ski pass at the bottom of the lift to a gate machine into which they insert their swipe card, each time through. Two machines are available at the ‘Pic blanc’ chairlift, and one is available at the ‘Plates’ chairlift. Each verification system is preceded by a queue which must never be greater than 25 skiers. The duration of the ski pass check for the skier is estimated to have a mean value of 5 s and a standard deviation of 3 s.

COMMENT 1.2.–

- All of these specifications derive from measurements made on location over several days. The specifications related to the technology and the workforce were supplied by the department of the ‘Levant’ local authority in charge of winter sports.

- This simulation does not take into account the purchase and sale of ski passes to skiers. Nevertheless, each skier should have one in their possession to use the pistes and take the ski lifts.

- The simulation should take place over 1 day, from 8:30 am to 6:00 pm.

- Warning: The schedule management uses a 24 h system (0:00:00 to 23:59:59).

1.3. Setting up the project in the ExtendSim 9 software

We will now construct the simulation in the ExtendSim software. For this, we work through a certain number of stages as presented in section 10.4.4 of Volume 1.

1.3.1. Definition of the principal parameters

To start, we define a new model: FILE menu, NEW MODEL.

Once the model is created, we define the time parameters of the simulation: RUN menu, SIMULATION SETUP.

Our simulation is discrete because the flow is composed of skiers (who are indivisible and countable).

The time will be managed according to a calendar, so we check USE CALENDAR DATES and choose 01/04/2015 for the START as defined by the design brief, as well as the start time of the simulation, which is 8:30:00.

By default, the unit of time is minutes (GLOBAL TIME UNITS) because it seems to be most-suited to the different future applications of the simulation.

The END TIME is set to 570 min, which is $570/60 = 9.5$ h, because our simulation should cover a day from 8:30:00 to 18:00:00 (Figure 1.2).

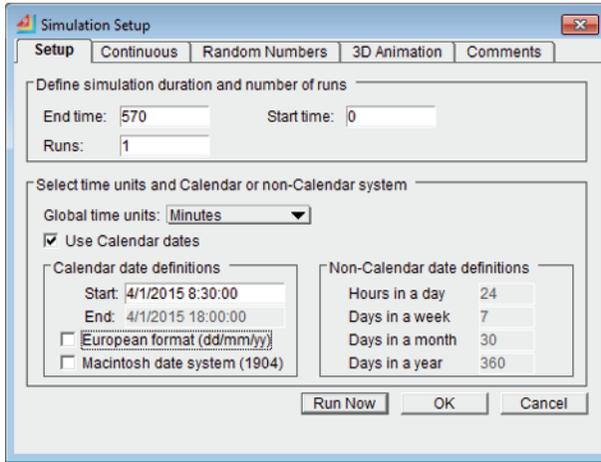


Figure 1.2. Settings for the simulation

To include our parameters, we will place the EXECUTIVE block from the 'Item.lix' library in our model, in the top left-hand corner.

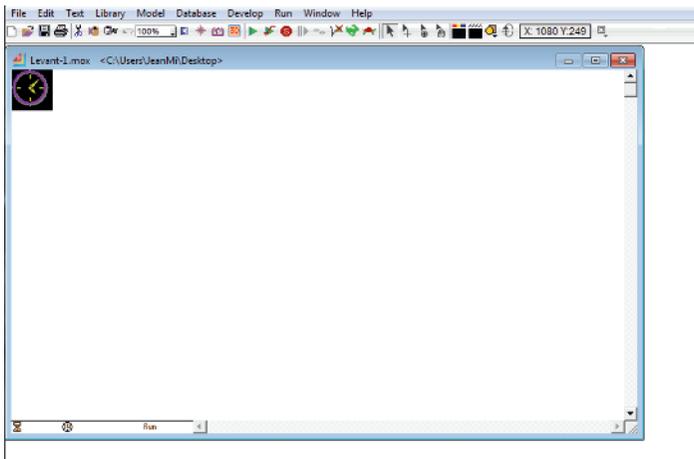


Figure 1.3. The new model with its EXECUTIVE block

1.3.2. Designing the model and inputting constraints

With the help of different blocks taken from the libraries (files with the extension ‘.lix’), we will now design and construct the functional organization chart of our simulation. At the same time, we will also input the constraints.

1.3.2.1. Schedules and generators

To simulate the arrival of skiers at the resort, we will use the CREATE block (‘Item.lix’ library) whose function is to create items in order to form a flow which, in our case, will be composed of skiers.

A generator can be associated with a statistical distribution and a time period. In our design brief, we have four different skier arrival frequencies, following a normal distribution (mean and standard deviation), dependent upon four schedules.

We must thus place four CREATE blocks associated with four SHIFT blocks (‘Item.lix’ library) in our model.

Take, for example the shift from 9:00 am to 10:30 am – a skier arrives, on average, every 5 s, with a standard deviation of 1.5 s, so we parameterize this block accordingly.

We start by creating the schedule which we will call ‘morning schedule’ (Figure 1.4).

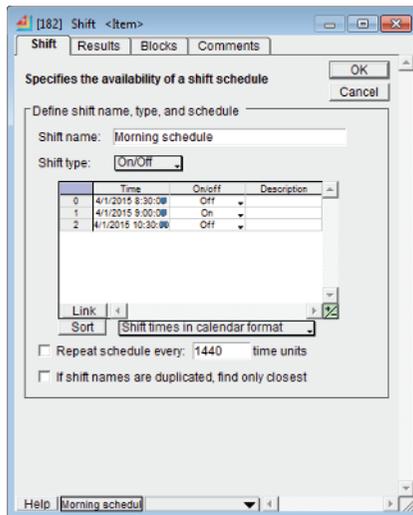


Figure 1.4. The configuration window for the 9:00 am to 10:30 am schedule

In Figure 1.4, we can see the name, the timeslot with a start time of 8:30 – OFF, corresponding to the start time of the simulation that we previously input in the SIMULATION SETUP window (section 1.3.1), an arrival time for the skiers, 9:00 – ON and a time at which the frequency changes, 10:30 – OFF.

The schedule is in the calendar format, which is easier to manage in our case because it is what has been chosen in SIMULATION SETUP

COMMENT 1.3.–

- A calendar must always have a start time equal to the start time input in the simulation parameters.

- To add or delete a row, you simply need to click on the green +/- box.

- The ON position indicates the start of an active schedule period, the OFF position indicates the end of one.

- The schedule can be in the numerical format, in which case, according to the unit chosen in SIMULATION SETUP, we specify the number of time units passed since 0 (the time at which the simulation starts).

We can now finalize our CREATE block with the arrival frequency of skiers that we input in the CREATION tab (Figure 1.5).

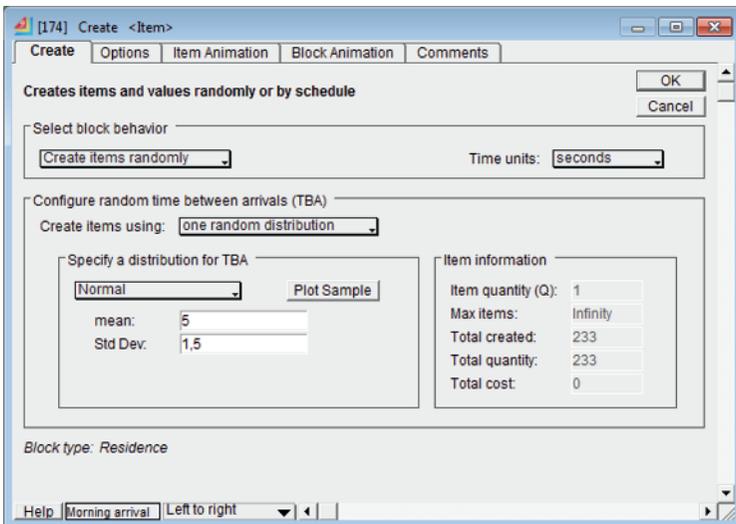


Figure 1.5. The CREATION tab of the CREATE block for the morning arrivals (9:00–10:30)

We continue onto the OPTIONS tab, in which we choose the ‘Morning shift’ calendar that we have just created (Figure 1.6).

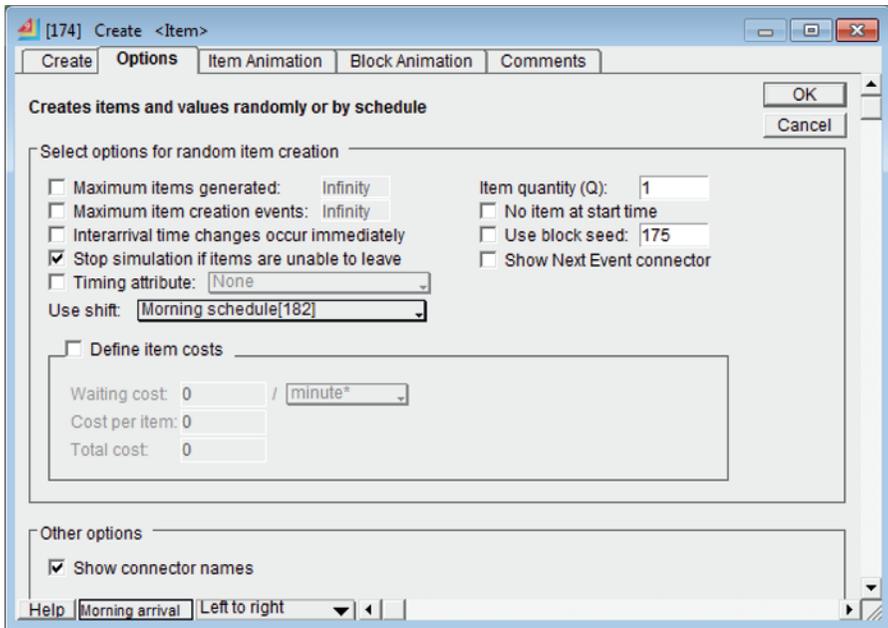


Figure 1.6. The OPTIONS tab of the CREATE block for arrivals between 9:00 and 10:30. We can see the choice of ‘Morning shift’ for the option USE SHIFT

In the same way, we generate three other CREATE blocks, associated with the three other SHIFT blocks.

COMMENT 1.4.– We can group the schedules 10:30–12:30 and 13:45–14:30 in the same SHIFT block since they have the same mean and standard deviation parameters.

We also add another SHIFT block which determines the operating times for the ski lifts and the opening/closing of the pistes, which is 9:00 am–5:30 pm.

In summary, the schedules and generators that we have made are:

- ‘Morning schedule’ with the ‘Morning arrival’ generator: 9:00–10:30;
- ‘Lunchtime schedule’ with the ‘Lunchtime arrival’ generator: 12:30– 13:45;

- ‘Day schedule’ with the ‘Day arrival’ generator: 10:30–12:30 and 13:45–14:30;
- ‘End of day shift’ with the ‘End of day arrival’ generator: 14:30–17:30;
- ‘Resort schedule’: 9:00–17:30.

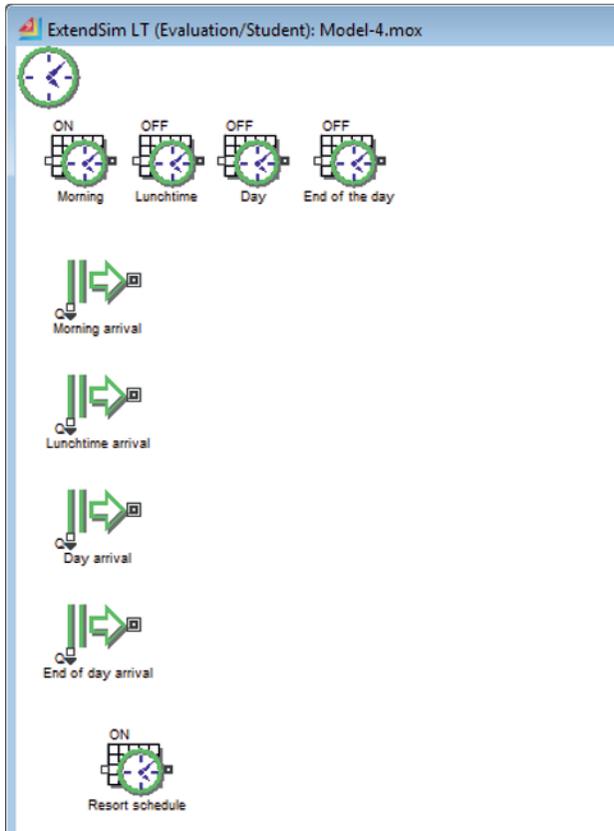


Figure 1.7. *The five SHIFT blocks and the four CREATE blocks*

1.3.2.2. Ski pass checks

Our skiers will now be directed toward one of the two ski lifts, the ‘Pic blanc’ chairlift or the ‘Des Plantes’ chairlift.

Upon arrival at the chairlifts, they will need to present their ski pass to the card reader and go through the turnstile.



Figure 1.8. *Two card readers with turnstiles*

The ‘Pic blanc’ chairlift has two card readers and the ‘Plates’ chairlift has one, which we will need to place in front of the queues (QUEUE block, ‘Item.lix’ library) to receive the skiers.

We are told in the design brief that these queues must not exceed 25 skiers. We cannot formalize this constraint, which is fully dependent upon our simulation, and we should instead treat it as a result of the simulation. We will discuss this further in the report and analysis stage (see section 1.3.7).

In order to make the skiers gather toward our chairlifts, we put in place a SELECT ITEM IN (4 inputs/1 output, ‘Item.lix’ library), then a SELECT ITEM OUT (which we will name ‘Chairlift choice’, ‘Item.lix’ library) so as to take account of the probabilities of each direction, being 64% toward ‘Pic blanc’ and 36% toward ‘Des Plates’.

Another SELECT ITEM OUT (which we will name ‘Queue choice’) will be placed in front of the queues (QUEUE block) at ‘Pic blanc’ in order to steer the

skiers toward the least congested queue (logically, the skier would move toward the shortest queue).

Since the ‘Des Plantes’ chairlift only has one queue, it should be sufficient to link the QUEUE + ACTIVITY blocks.

The ski pass checks are defined using ACTIVITY blocks. These blocks will be configured following a normal distribution with a mean value of 5 s and a standard deviation of 3 s for each skier (as indicated in the design brief). We will also use the ‘Resort schedule’, as defined previously.

Figure 1.9. Parameters for the ‘Pass checks’ ACTIVITY blocks (Distribution: Normal, mean = 5, standard deviation = 3)

Once all of these blocks are in place, we can connect them together to obtain the model shown in Figure 1.10.

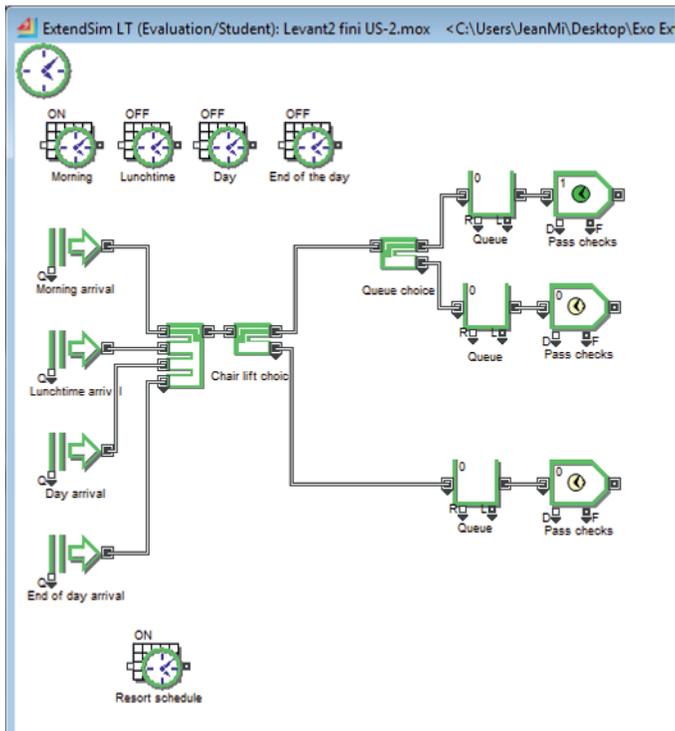


Figure 1.10. *Our model with queues, ski pass checks, the selectors and connections*

COMMENT 1.5.– It is worth regularly saving your model (FILE menu – SAVE) to avoid losing your work, or to be able to return to an earlier version.

We now move on to inputting the different constraints.

On the ‘Chairlift choice’ SELECT ITEM OUT block, which directs the skiers toward one or other of the chairlifts, we input 0.64 (64%) toward ‘Pic blanc’ and 0.36 (36%) toward ‘Plates’.

For the ‘queue choice’ selector, we encounter the problem of how to direct the skier toward the least congested queue.

To resolve this problem, we will place a MAX & MIN block, taken from the ‘Value.lix’ library, in our model. Then, we will direct the value (the number of skiers) contained in of each of the two queues toward it, so that it sends the skier to the most appropriate queue (whichever is shortest).

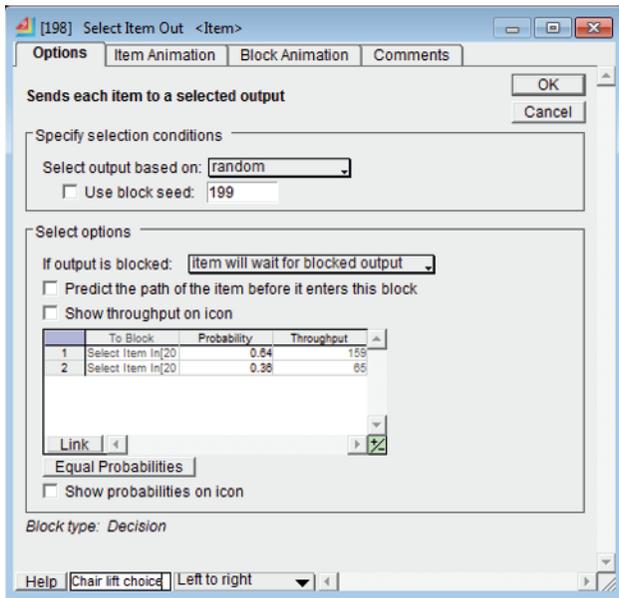


Figure 1.11. The parameters of the 'Chairlift choice' selector (Probability: 0.64 and 0.36)

The configuration of the MAX & MIN block is given in 1.12: OUTPUT THE: MINIMUM VALUE.

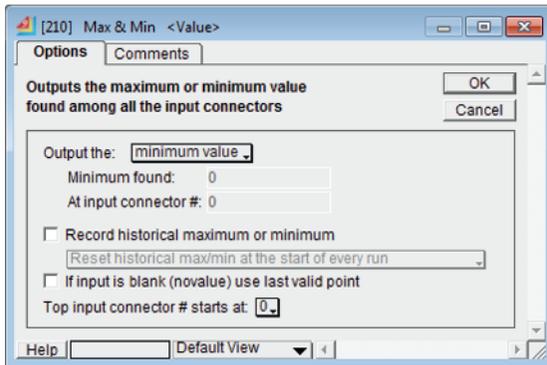


Figure 1.12. The configured MAX & MIN block (set to MINIMUM VALUE)

The configuration of the 'Queue choice' selector is shown in Figure 1.13: CHOOSE EXIT: BY SELECT CONNECTOR.

COMMENT 1.6.– In order to simplify and streamline the model, we can use labels to replace the connections, for example, in our model the labels Q1 and Q2 manage the queues and the routing of skiers at the ‘Pic blanc’ chairlift.

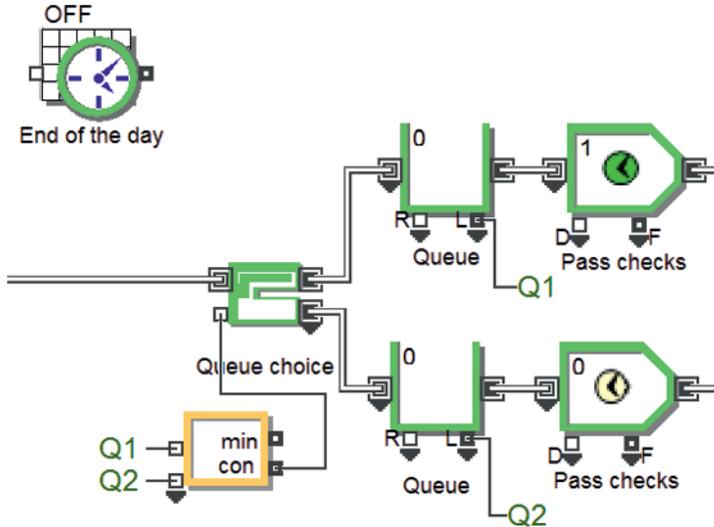


Figure 1.15. The two labels Q1 and Q2 simulating the connections between the QUEUE blocks and the MIN & MAX block for the ski pass check at the ‘Pic blanc’ chairlift

1.3.2.3. Transporting the skiers

Once their ski passes have been checked, the skiers queue in groups of four for ‘Pic blanc’ and groups of three for ‘Plates’, for the operator to assign them a chair. When they are sat down, the chairlift takes them to the drop-off point, where each skier chooses which piste to take.

We will start by forming batches of three or four skiers, representing a chair, via a BATCH block (‘Item.lix’ library) which we configure by inputting the QUANTITY NEEDED (Figure 1.16).

Behind each of these BATCH blocks, we will place an activity simulating the allocation of the chairs to the skiers. This will function according to the resort schedule, and each chair allocation has a constant duration of 18 s for the ‘Pic blanc’ chairlift and 15 s for the ‘Plates’ chairlift.

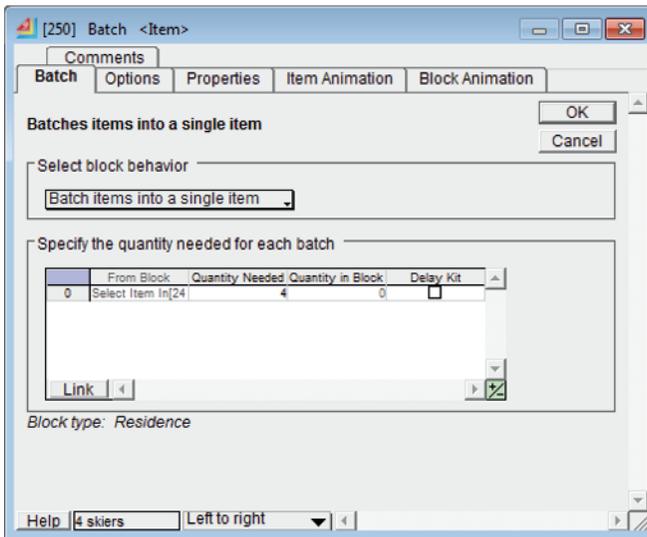


Figure 1.16. Configuration of the BATCH block (quantity needed = 4) for four skiers ('Pic blanc')

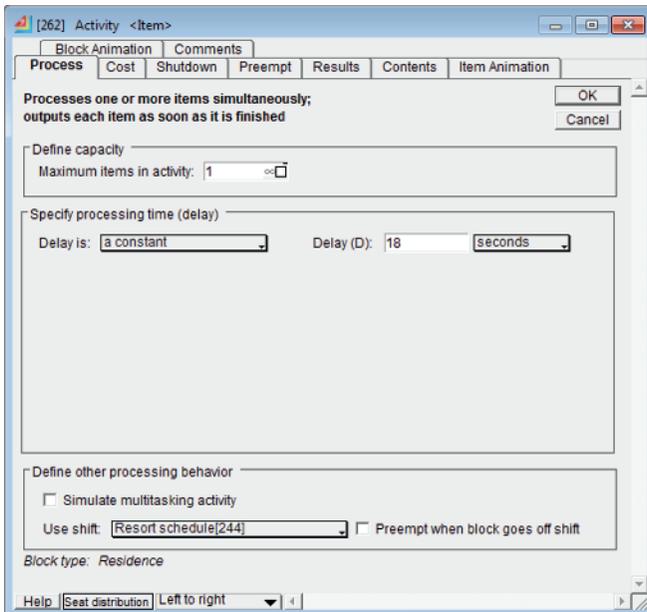


Figure 1.17. Parameters for the chair supply blocks (schedule: 'Resort shift' and period: 18 s constant)

The skiers are transported by the chairlift to the summit they have chosen. The duration of this journey is 9 min for ‘Pic blanc’ and 6 min for ‘Des Plates’. For this action, we will use a CONVEY ITEM block (‘Item.lix’ library).

The capacities of these conveyors are:

- for ‘Pic blanc’: $(9 \times 60 \text{ s}) / 18 \text{ s} = 30$ batches (of four skiers);
- for ‘Des Plates’: $(6 \times 60 \text{ s}) / 15 \text{ s} = 24$ batches (of three skiers).

The schedule used is ‘Resort schedule’.

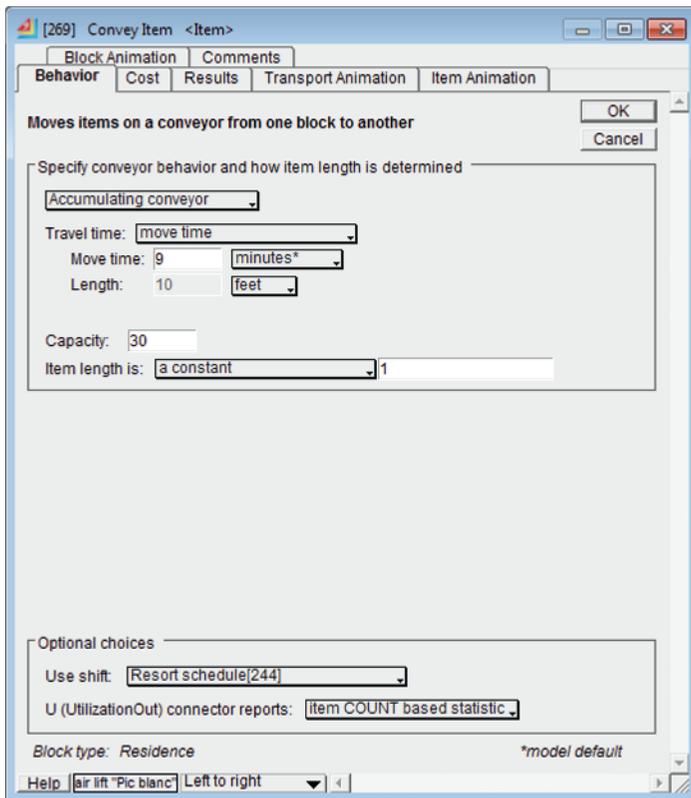


Figure 1.18. Configuration of the CONVEY ITEM block simulating the ‘Pic blanc’ chairlift (journey time, duration = 9 min, capacity = 30, schedule: ‘Resort schedule’)

When the chairlift arrives, the skiers must all be able to leave individually, so we split the batch (chair) using an UNBATCH block (‘Item.lix’ library).

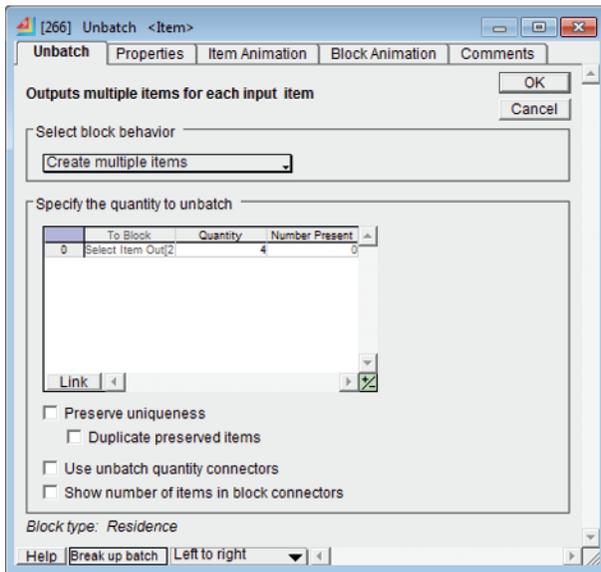


Figure 1.19. Configuration for splitting up the batches on 'Pic blanc' with an UNBATCH block (quantity = 4)

Our new model should resemble the one shown in Figure 1.20.

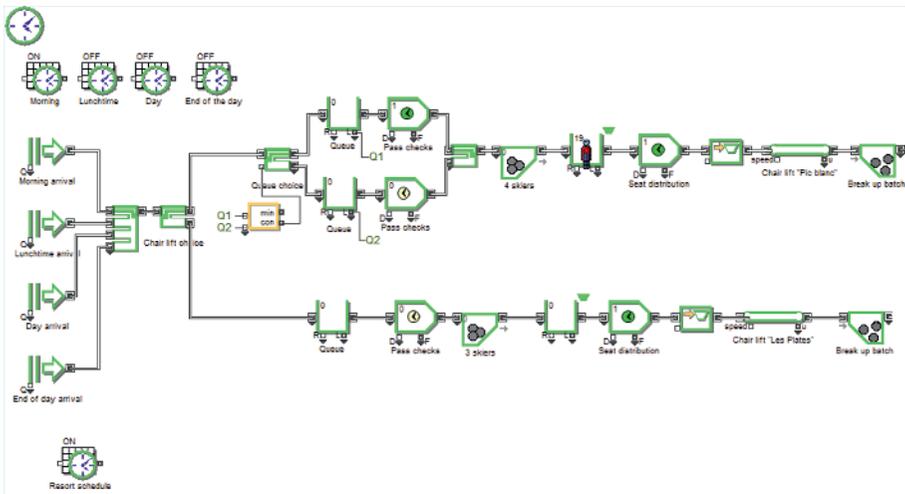


Figure 1.20. Our model from the arrival of the skiers to the arrival of the chairlifts at the top of the pistes

1.3.2.4. Ski pistes

The skiers have now arrived at the top of the pistes and will be able to ski, we must therefore model all of the pistes and their specifications: possible routes, descent times and choices.

Each piste will be represented by an ACTIVITY block and SELECT ITEM IN and SELECT ITEM OUT blocks will be used to formalize the available route choices (see Figure 1.1, the map of the resort).

Figure 1.22 represents the part of the model simulating the network of different pistes. The SELECT ITEM IN situated on the left will be connected to the two UNBATCH blocks, the top one being the 'Pic blanc' branch and the bottom one being the 'Plates' branch.

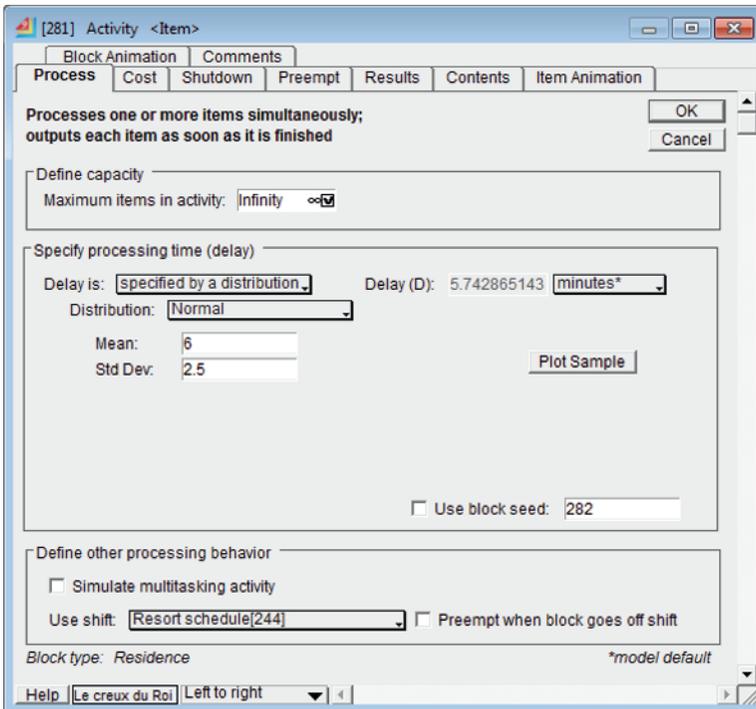


Figure 1.21. An example of piste configuration, here 'Le creux du Roi' (Maximum number in the activity: ∞ , Distribution: Normal, Mean: 6 min, Standard deviation: 2.5 min)

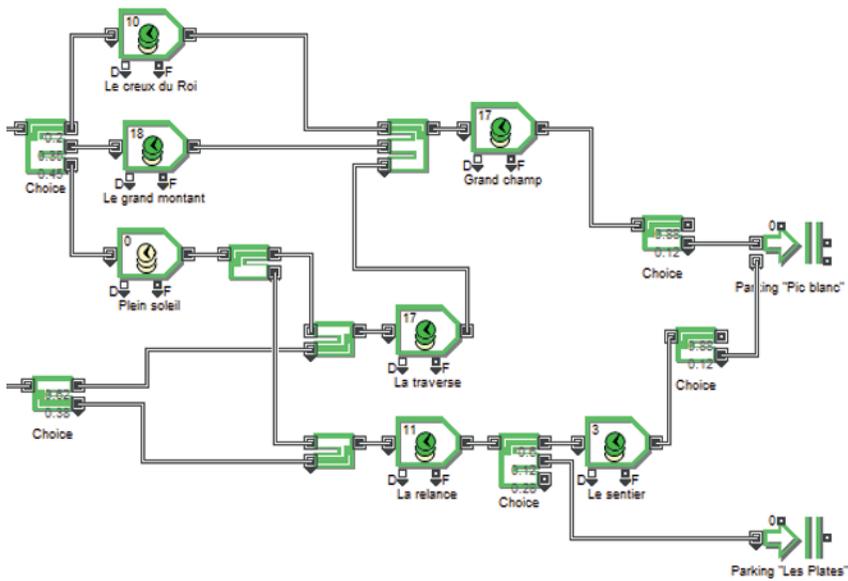


Figure 1.22. *The piste network, composed of ACTIVITY, SELECT ITEM IN and SELECT ITEM OUT blocks. Note: the probabilities are given on each of the EXIT SELECTOR blocks*

We will also include two EXIT blocks to represent the routes back to the parking lots for skiers deciding to stop skiing.

Two SELECT ITEM OUT blocks ('Item.lix' library) are placed before the exits allowing the skier to continue skiing by returning to each of the two chairlifts.

The probabilities for all of the selectors are those given in the design brief.

All of the pistes follow the 'Resort schedule' opening times.

Since the maximum number of skiers on the piste has not been specified, we assume that it is infinite.

To direct the skiers toward the chairlifts from the selectors situated behind the 'Grand champ', 'Le sentier' and 'La relance' pistes, we add, behind the 'Chairlift choice' selector, two input selectors – 'Towards Pic blanc' and 'Towards Les Plantes' – as shown in 1.23, and we connect everything together.

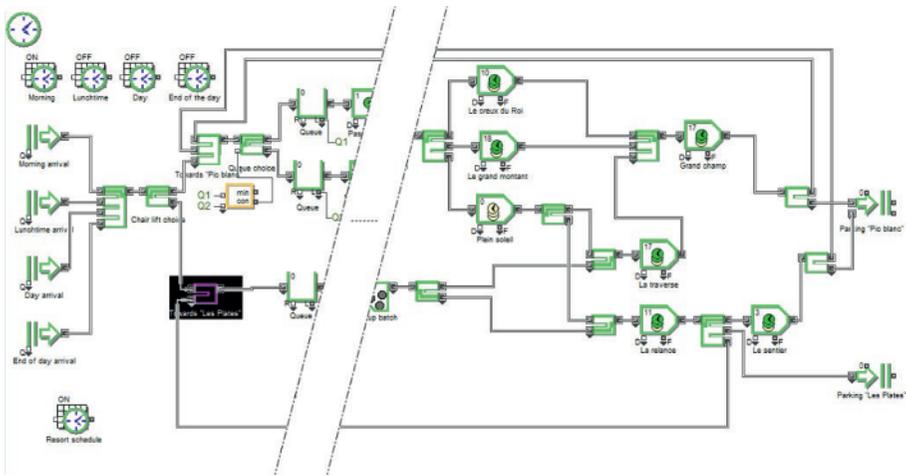


Figure 1.23. The model with the routing of skiers toward the chairlifts via the *SELECT ITEM IN* blocks: toward 'Pic blanc' and toward 'Plates'

1.3.3. Definition of flows

Having completed the design and its configuration following the design brief, we now have to define the flows which will be instigated by the 2D animation of our model.

For each of the four generators, we specify a type of item to animate, here we choose `PERSON_M`. The flows circulating around the model will be composed of these items, so we do not have to specify this elsewhere, they will automatically propagate through all of the blocks (see Figure 1.24).

1.3.4. Running the simulation

We can now run the simulation, after checking `2D ANIMATION` and `ADD CONNECTION LINE ANIMATION` in the `RUN` menu. To do this, you simply have to click on the run icon found in the top toolbar.

The simulation can be controlled *via* the toolbar icons, whose functions are as follows:

- run the simulation: starts the simulation if all the parameters are correct;
- run Optimization or Scenarios: optimizes the simulation or controls the scenario if an `OPTIMIZER` or `SCENARIO` block is present in the model;

- stop: stops the simulation with no option to continue from this point later;
- pause/Continue: stops the simulation, but with the ability to restart from the point where it was stopped;
- step: carries out one step in the simulation followed by a pause;
- animation on/off: shows or hides the 2D animation while leaving the simulation to finish;
- animation Faster: accelerates the animation and reduces the overall duration of the simulation;
- animation Slower: slows the animation and increases the overall duration of the simulation.

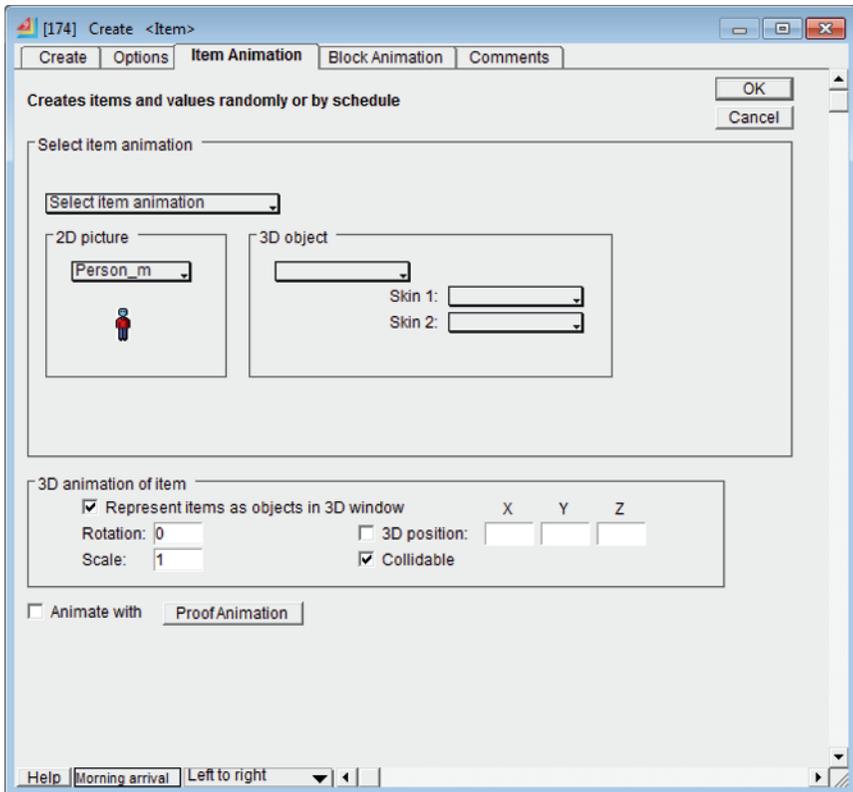


Figure 1.24. The configuration of flows, here the transported items are of the PERSON_M type

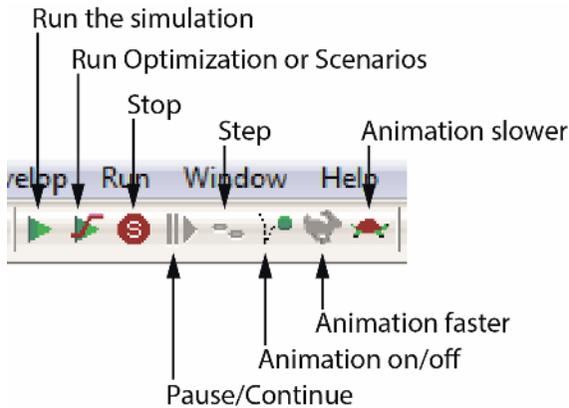


Figure 1.25. The icons on the main toolbar which control the simulation run

COMMENT 1.7.–

– To reduce the simulation run-time, you can un-check *ADD CONNECTION LINE ANIMATION*, which causes the items simulating the flows to only appear in certain blocks.

– At the bottom-left of the model window, an hourglass indicates the time left until the simulation ends, in minutes and seconds, and the time passed relative to the actual duration as set in the parameters (here 570 min, from 8:30 am to 6:00 pm – the duration of the simulation set by the design brief).

– In certain cases, the items can change in the middle of the model. This often happens in industrial processes, where components are transformed into subassemblies, which can themselves become larger objects. Item changes thus take place in certain blocks, where the outgoing items are different from the incoming items.

1.3.5. Creation and allocation of resources

In the current state, our simulation is functional. However, the workforce (composed of two operators) is still not in place.

The role of these operators, assigned to each ski lift, is to provide the chairs to the skiers whenever a row (a batch) of three or four skiers is formed.

To address this specification, we will have to create a RESOURCE POOL QUEUE to manage the workforce.

We place this RESOURCE POOL QUEUE block (QUEUE block, 'Item.lix' library) in front of our 'Seat distribution' ACTIVITY.

This ACTIVITY will be fed by a RESOURCE POOL block ('Item.lix' library) composed of two operators who work according to the opening times of the resort, from 9:00 am to 17:30 pm, at a cost of \$18.25 per hour.

We insert a RESOURCE POOL block in our model and input the necessary parameters.

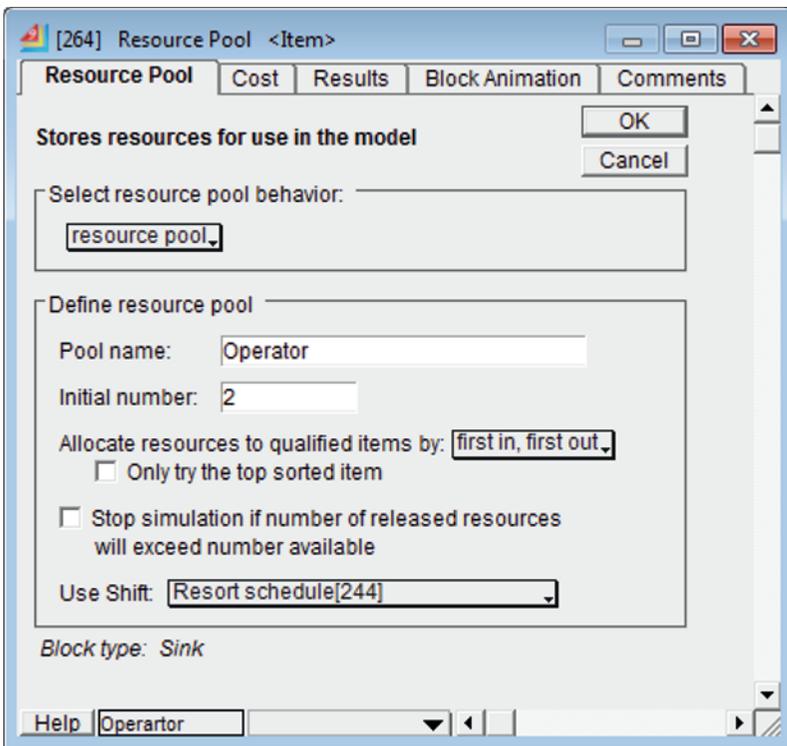


Figure 1.26. Parameters for the 'Operators' RESOURCE POOL (Name of the pool: Operator, Initial number: 2, schedule: 'Resort schedule')

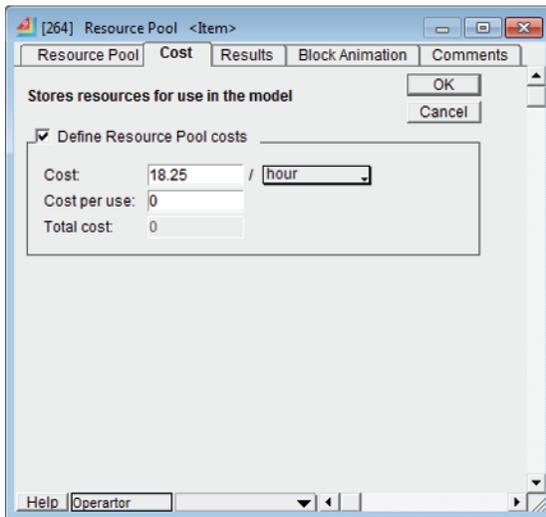


Figure 1.27. Operator cost configuration (Cost = \$18.25/h)

Once the RESOURCE POOL block exists, we can insert the two RESOURCE POOL QUEUE blocks and assign them an operator.

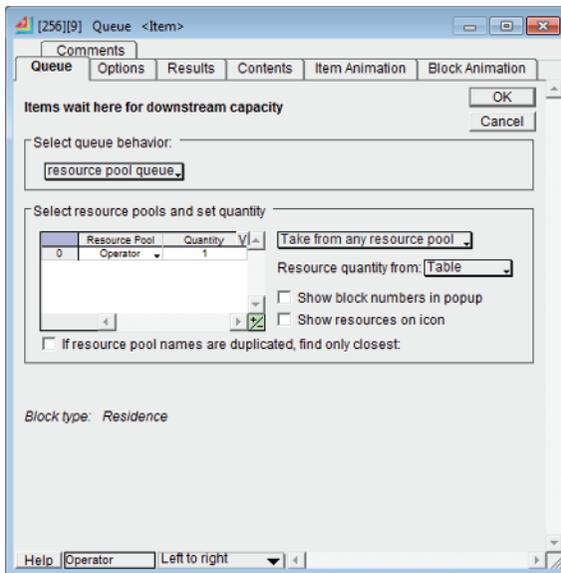


Figure 1.28. Parameters for the QUEUE RESOURCE blocks for the operators (queue resource, Pool: Operator and Quantity = 1)

Between each chair allocation, the operator must wait 15 or 18 s, or even longer if no skier is present (which is unlikely). We will thus free them of this work, while they wait, which is the role of the RESOURCE POOL RELEASE block ('Item.lix' library) (Figure 1.29).

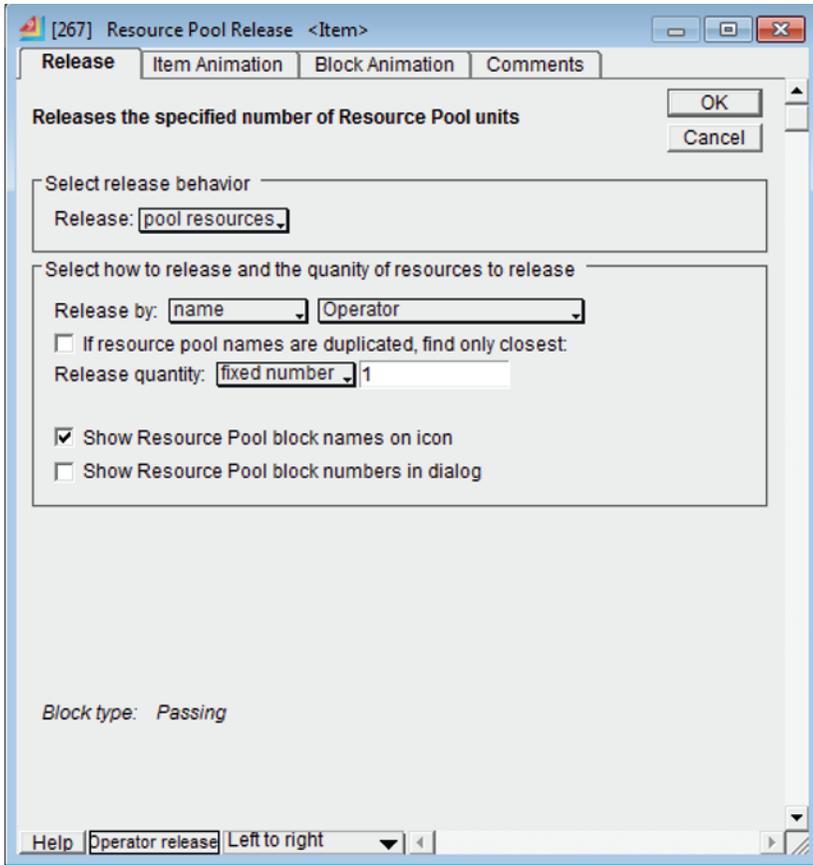


Figure 1.29. Configuration of the RESOURCE POOL RELEASE block (name: operator, fixed number = 1)

We place this block behind the 'Seat distribution' ACTIVITY block.

Our updated model, including the two operators, should resemble the one shown in Figure 1.30.

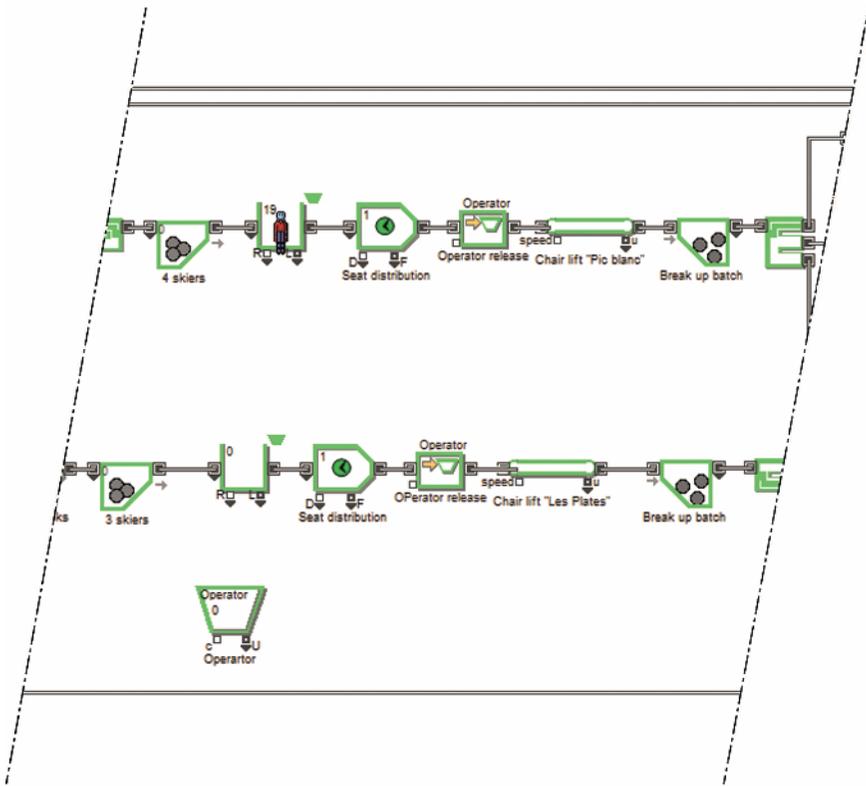


Figure 1.30. *The updated section concerning the chairlift management. We can see the RESOURCE POOL block (at the bottom), the two RESOURCE POOL QUEUE blocks and the two RESOURCE POOL RELEASE blocks*

COMMENT 1.8.– The RESOURCE POOL QUEUE block is a QUEUE block from the ‘Item.lix’ library, which we have configured to be in the QUEUE RESOURCE mode. To differentiate it, the icon representing it has a small, green trapezium above it.

1.3.6. Rerunning the simulation

We can rerun the simulation. Check that SHOW 2D ANIMATION and ADD CONNECTION LINE ANIMATION are checked in the RUN menu, otherwise no movement in the model will be visible.

1.3.7. Generating a report and analysis

Once our simulation model is operational, it is crucial to have an overall view of all the process data in order to check if certain specifications have been met and perhaps to make modifications.

It is the role of the report generator to amalgamate all of the results into a text-based report.

COMMENT 1.9.– For very complex models, the simulation can take a very long time. In order to reduce this time, we can set ExtendSim to conduct the whole simulation without any animation. In this case, the run-time is significantly shortened without affecting the calculation results or the values produced by the software. To carry out a simulation without animation, you must simply un-check 2D ANIMATION in the RUN menu before running the simulation.

To activate the report generator, the GENERATE REPORT option must be checked in the RUN menu.

Beforehand, we can choose the type of report generated from a list of three:

- dialogs (text file): gives all of the block input/output parameters and the information in the comments fields;

- statistics (text file): gives all of the final values of certain output parameters in a table format, ready for exporting as a table;

- statistics (DB): same as the previous option, but generates a database with tables. This database can be visualized and manipulated *via* the ExtendSim database management tool.

We are interested in the second type, ‘Statistics (text file)’, which will give us all of the important data from the simulation of our model in a coherent state.

In order to not overload our report, we will choose from all of the blocks only those whose calculated statistical results merit our attention.

To start, we select the ‘Arrival’ (CREATE), ‘Queue’ (QUEUE), ‘Pass checks’ (ACTIVITY), ‘Chairlifts’ (CONVEY ITEM), ‘Pistes’ (ACTIVITY), ‘Operator’ (RESOURCE POOL) and ‘Parking lot’ (EXIT) blocks. To do this, we hold down the CTRL button on the keyboard and click on each of these blocks.

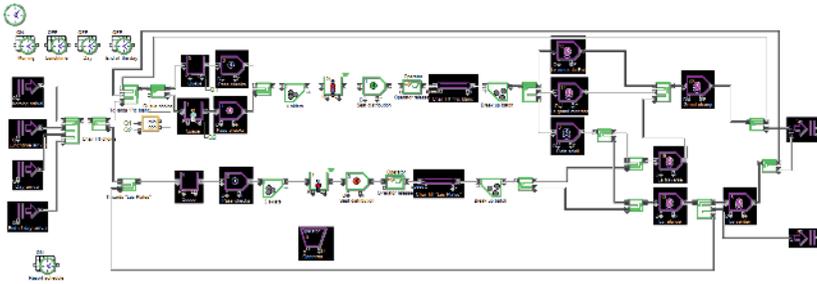


Figure 1.31. Our model with the blocks selected for the report

To include these blocks in our future report, select ADD SELECTED TO REPORT in the RUN menu.

When we now launch the simulation, a dialog box opens, asking us the name of the report ('report.txt' by default) and the folder we want to save it in.

By clicking on the SAVE button, the simulation runs and then the report is displayed in a text window and is saved.

!report.txt

Statistics Report - 6/17/2015 9:57:24 PM
Run #0

ACTIVITIES												
Block Label	Number	Name	Length	Ave Len	Max Len	Len Wait	AveWait	MaxWait	Arrive	Depart	Preempt	Util
Poss checks	232	Activity	1	0.59305	1	0	0.14078	0.00462	0.27455	3641	0	0.57044
Poss checks	233	Activity	1	0.18743	1	0	0.08097	0.08422	0.22043	913	0	0.14225
Poss checks	237	Activity	0	0.16452	1	0	0.04344	0.00351	0.22497	1123	0	0.17565
Chair lift "Pic blanc"	245	Convey Item	10	9.28709	11	9	9	9	556	556	0	0.2129
Chair lift "Les Plateau"	270	Convey Item	10	3.93684	11	6	6	6	374	374	0	0.16484
Le creux du bois	281	Activity	0	11.7525	23	0	0.55775	5.97139	12.6097	1139	0	0
Le grand montant	282	Activity	0	13.4023	25	0	0.01293	7.04085	12.9404	1085	0	0
Plein soleil	283	Activity	0	0	0	0	0	0	0	0	0	0
La trapozoc	284	Activity	0	11.5619	42	0	7.75567	9.89279	21.2621	741	0	0
La relation	285	Activity	0	4.40842	21	0	7.05454	6.58527	11.5046	381	0	0
Le sentier	286	Activity	0	4.02352	16	0	19.757	11.132	22.2643	206	0	0
Grand chaup	313	Activity	0	26.0939	51	0	7.41272	5.01637	13.2251	2965	0	0

QUEUES												
Block Label	Number	Name	Length	Ave Len	Max Len	Len Wait	AveWait	MaxWait	Arrive	Depart	Reneges	Util
Queue	214	Queue	29	1.32547	29	0	0.03216	0.0353	0.50247	3570	0	0.25549
Queue	215	Queue	28	1.12349	28	0	0.07118	0.52346	941	913	0	0.0918
Queue	234	Queue	1	0.05265	3	0	0.00894	0.33944	1124	1123	0	0.00374

RESOURCES												
Block Label	Number	Name	Total resources	Resources in use	Resources available	Utilization	Items waiting					
Operator	264	Resource Pool	1	1	0	0.64113	671 345.615 94.616					

ROUTING												
Block Label	Number	Name	Total quantity	Total created	Total cost							
Morning arrival	174	Create	1073	1073	0							
Icebreak arrival	175	Create	489	489	0							
Day arrival	176	Create	724	724	0							
End of day arrival	178	Create	536	536	0							

Line 44 | Code Completion (F9) |

Figure 1.32. The text window with our report in a table format

COMMENT 1.10.–

The GENERATE REPORT option in the RUN menu remains checked if it has already been checked once and a new report is generated for each simulation run.

A dialog box asks you its name. If you do not change it, the old report will be overwritten. Hence, you must un-check this option if you do not want any further reports.

The format of the report stays the same unless it is deliberately changed.

Other report options are available in the RUN menu: ‘REMOVE ALL FROM REPORT’, ‘ADD ALL TO REPORT’, etc.

In the design brief (section 1.2.2) and slightly later on, where the queues are constructed (section 1.3.2.2), a maximum queue size of 25 skiers was specified.

Looking at the report, we can see that the maximum lengths of the three queues were 23, 14 and 22 skiers, respectively, which satisfies the specified constraint.

1.3.8. Development, enhancement and improvement

We will continue by improving the process involved in our model. To do this, new specifications as well as certain result indicators will be added.

1.3.8.1. Categories of skiers

After taking some surveys during the previous season, the sports department of the ‘Levant’ local authority confirms the following figures:

- 38% of skiers are men.
- 36% of skiers are women.
- 26% of skiers are children (under 16 years old).

To sort the skiers into the three categories (men, women and children), we will generate them randomly, as the skiers arrive.

We start by placing a RANDOM NUMBER block taken from the ‘Value.lix’ library, in our model, next to the four ‘Arrival’ ACTIVITY blocks as well as a SET block from the ‘Item.lix’ library.

We connect them together as shown in Figure 1.33.

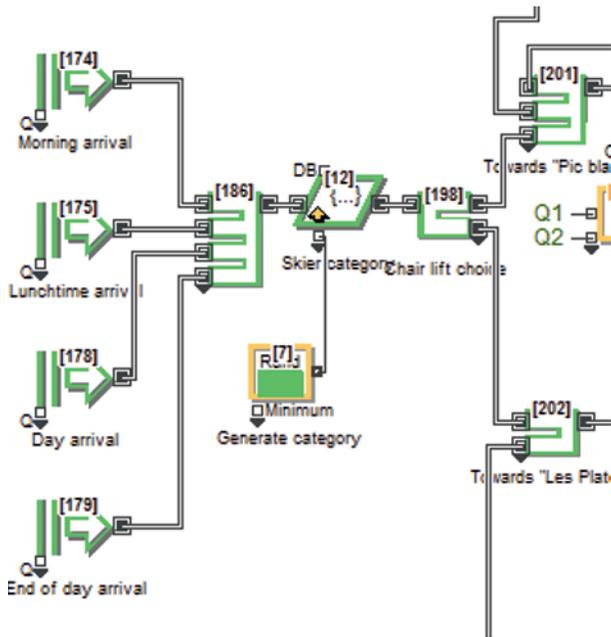


Figure 1.33. In the center, the RANDOM NUMBER blocks ('Generate category') and SET ('Skier category') in our model

COMMENT 1.11.– In Figure 1.33, the numbers of the blocks appear, which is an option given in ExtendSim – in the MODEL menu, check SHOW BLOCK NUMBERS.

Having opened the SET block, we choose NEW STRING ATTRIBUTE from the PROPERTY NAME column to create the skier categories.

A dialog box opens, in which we input 'CatSkier' (which will be the general variable governing the three categories of skiers), and then click on OK.

The EXECUTIVE block dialog box opens and we see our variable in the left-hand table, in the STRING ATTRIBUTE column.

We now input our three categories, 'man', 'woman' and 'child' into the CATSKIER column of the right-hand table, as shown in Figure 1.34.

We must again assign a different item to each of our categories in order to be able to visually differentiate them in the 2D animation.

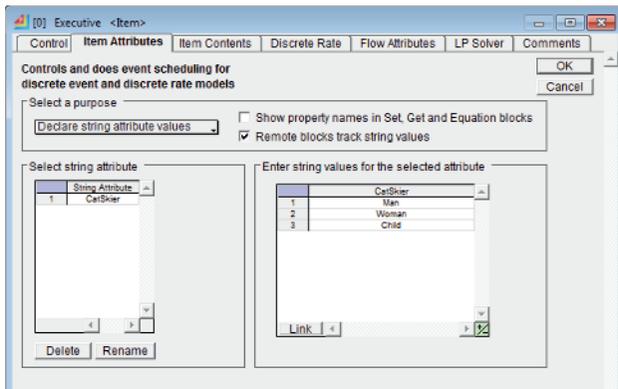


Figure 1.34. The EXECUTIVE block dialog box with its two tables containing the network attribute variable, ‘CatSkier’ (left-hand table) and the three network value categories (right-hand table)

We open the SET block and select the ITEM ANIMATION tab. Having chosen CHANGE ITEM ANIMATION USING PROPERTY and CatSkier in the two drop-down menus, we assign over three rows (green +/- box), the following items for each of the categories:

- PROPERTY VALUE: ‘Man’, 2D SYMBOL: ‘Person_m’;
- PROPERTY VALUE: ‘Woman’, 2D SYMBOL: ‘Person_f’;
- PROPERTY VALUE: ‘Child’, 2D SYMBOL: ‘Person_labor’.

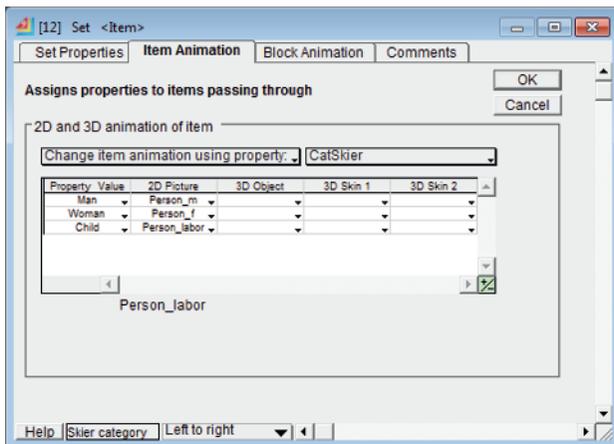


Figure 1.35. Configuration of the SET block, with the categories (attributes) and their 2D symbols

Next, in the RANDOM NUMBER block, we input the probabilities (in the form of decimals) corresponding to the figures given, i.e. 0.38 (38%) for men, 0.36 (36%) for women and 0.26 (26%) for children.

The values are specified by distribution in an EMPIRICAL TABLE with three values (green +/- box).

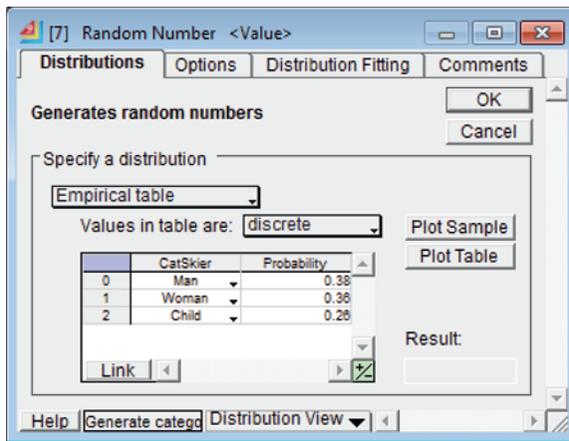


Figure 1.36. Configuration of the probabilities of our categories in the RANDOM NUMBER block

We can launch a simulation after checking SHOW 2D ANIMATION and ADD CONNECTION LINE ANIMATION in the RUN menu. The different items representing the different skier categories should appear on the connections and inside certain blocks.

1.3.8.2. Chairlift monitoring curve

In order to have a better picture of how the skiers are transported on each of the chairlifts, we will link the PLOTTER, DISCRETE EVENT block from the 'Plotter.lix' library to the output 'u' of each of the CONVEY ITEM blocks. This output 'u' measures the number of items conveyed.

This plotter block will display, in real-time, how the number of batches of skiers who go through each of the two chairlifts varies throughout the course of the simulation (570 min), in the form of two plots.

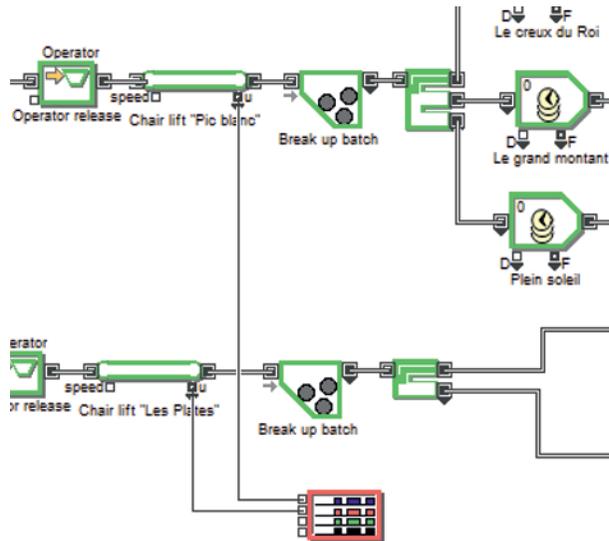


Figure 1.37. The *PLOTTER, DISCRETE EVENT* block connected to the outputs 'u' of the *CONVEY ITEM* blocks (chairlifts)

We still need to configure this block.

When we open the block, we find a toolbar from which we can define the necessary configuration parameters.

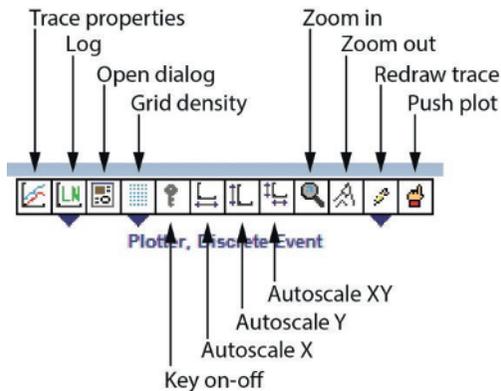


Figure 1.38. The toolbar for *PLOTTER* blocks

We click on the icon that is furthest to the left (the ‘Trace properties’ tool). A table with nine columns appears in which we can modify, from left to right:

- text describing the trace;
- the trace color (seven colors);
- the trace width (five widths);
- the trace pattern (four patterns);
- the trace style (interpolated, stepped or points);
- the trace symbols (dots, squares, + signs, circles, etc.);
- the number format for the data pane (general: Gen, decimal: x.xx, integer: xxx and scientific notation: x.xe);
- the plot axis for the trace (the left-hand axis, Y1, or the right-hand axis, Y2);
- the visibility (visible: open eye or invisible: closed eye).

We fill in the table as shown in Figure 1.39.

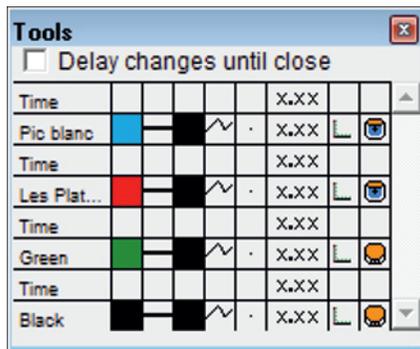


Figure 1.39. *The parameters to be input and chosen in the trace properties window. For a color version of this figure, see www.iste.co.uk/reveillac/modeling3.zip*

We then select the third tool from the left (the ‘Open dialog’ tool) and configure it by checking SHOW PLOT DURING SIMULATION (the plot will be traced in real-time during the simulation), SHOW INSTANTANEOUS QUEUE LENGTH (the queue length will be visible in zero time), AUTOSCALE DURING SIMULATION (the plot scale will be recalculated in real-time as new data arrive) in the drop-down menu.

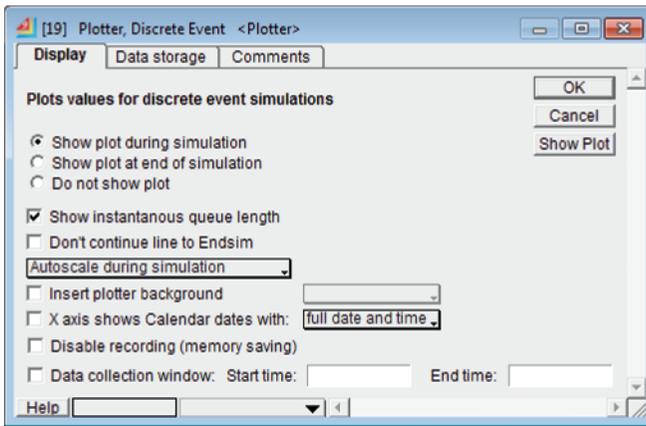


Figure 1.40. Configuration of the dialog tool

We can rerun the simulation, the plotter window will open and the trace plots itself in real-time throughout the simulation.

A table situated underneath the plot shows the key figures (time and number of items/batches) for each point of the trace for each chairlift.

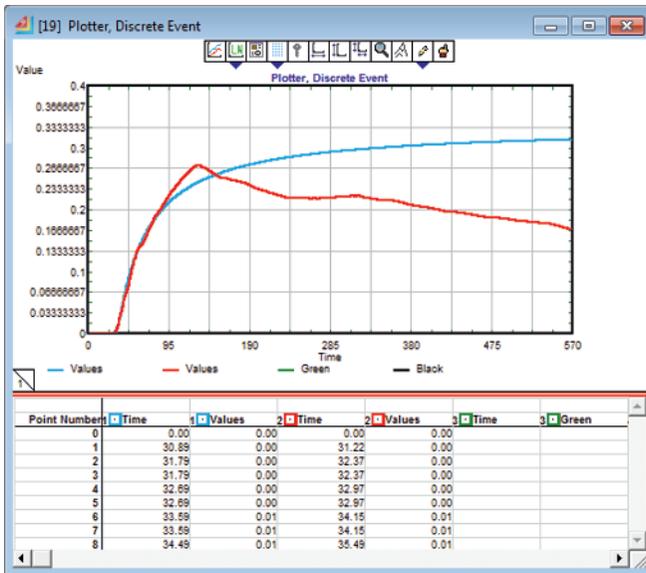


Figure 1.41. The plot display window with its data-tracking table. For a color version of this figure, see www.iste.co.uk/reveillac/modeling3.zip

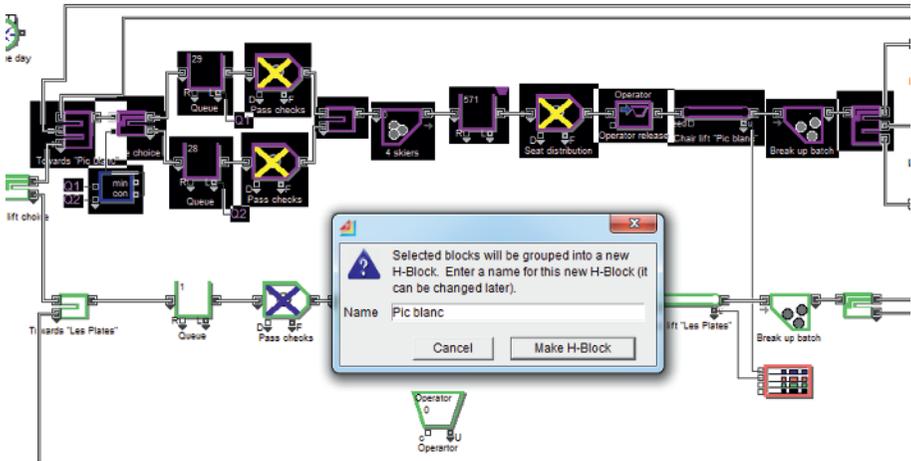


Figure 1.43. Creating the 'Pic blanc' H-block

To open the H-block, we can right-click on it and select OPEN STRUCTURE. In the window that opens (which is divided into four zones), we can make modifications, reorganize the inputs/outputs, change the appearance of the block, change the connections, etc.

The full variety of available features goes far beyond the scope of this chapter, and they will not all be described here.

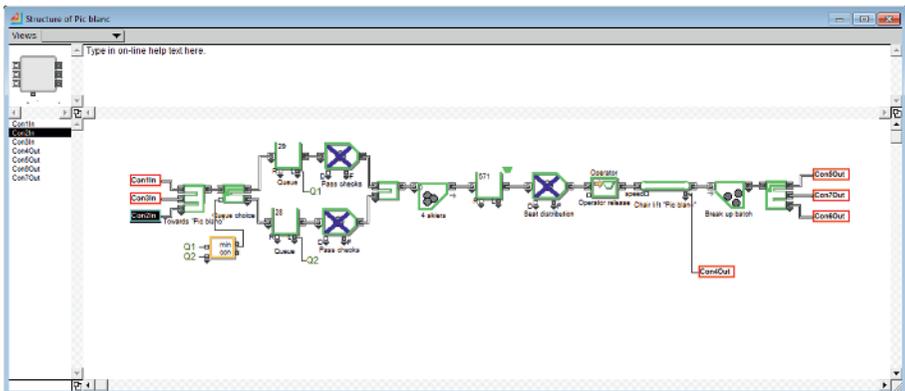


Figure 1.44. The reorganized 'Pic blanc' H-block structure. We can see the graphical representation (at top-left), the list of inputs and outputs (bottom-left), the help text (top-right) and the submodel of the H-block with its internal inputs/outputs

By applying this hierarchical technique, we can create all of the H-blocks proposed above, and change their appearance to end up with the model shown in Figure 1.45.

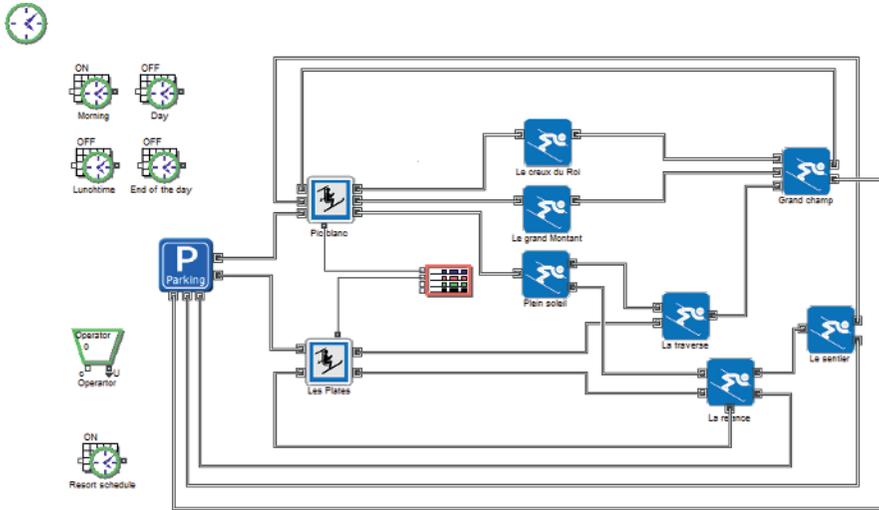


Figure 1.45. Our model with all of the H-blocks. The gray squares that represent each of the blocks by default have been replaced by logos

1.3.10. Appearance design

It is possible to greatly improve the interface of a 2D model by adding text, button commands, menus, dialog zones, etc.

Several tools exist to enable this:

- text, image and logo management;
- customized function creation from blocks of the ‘Utilities.lix’ library;
- configuration or attribute cloning from the dialog boxes.

The top toolbar has icons offering a variety of graphical functions, some linked to particular menus.

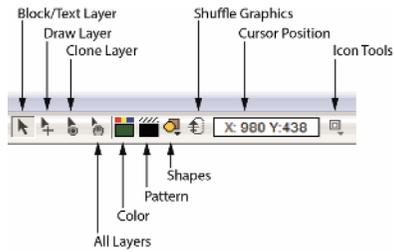


Figure 1.46. *Toolbar icons that can be used changing the design, among other things*

We will create:

- a title linked to a logo;
- a button for running the simulation;
- a button for pausing the simulation;
- two interactive dialog zones for configuring the transport time for each ski lift and the arrival frequency of the chairs.

We start by inputting the text for the title and the two dialog zones (double-click at the bottom of the model and use the TEXT menu), as in Figure 1.47. The two boxes are made using the ‘Graphics layer’ tool, and their color can be set with the ‘Colors’ tool. The logo is put in place by copying and pasting a preselected jpeg image.

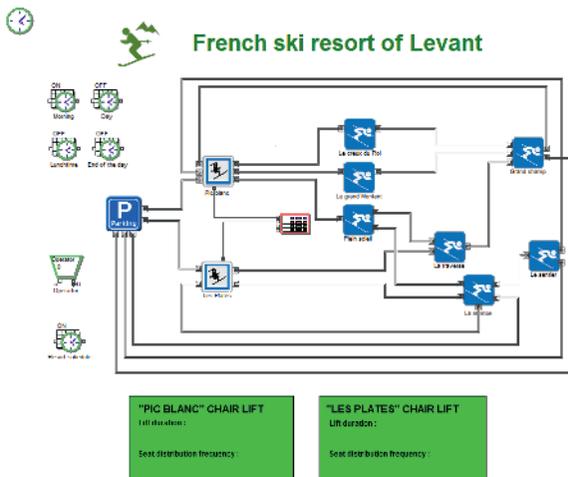


Figure 1.47. *The design elements: title, logo, dialog zones and boxes*

We clone the '9 minutes* duration' and '6 minutes* duration' attributes, the two 'Chairlift' CONVEY ITEM blocks and the '18 second period (P)' and '15 second period (P)' attributes from the two 'Seat distribution' ACTIVITY blocks into each of our zones using the 'Clone layer' icon on the toolbar.

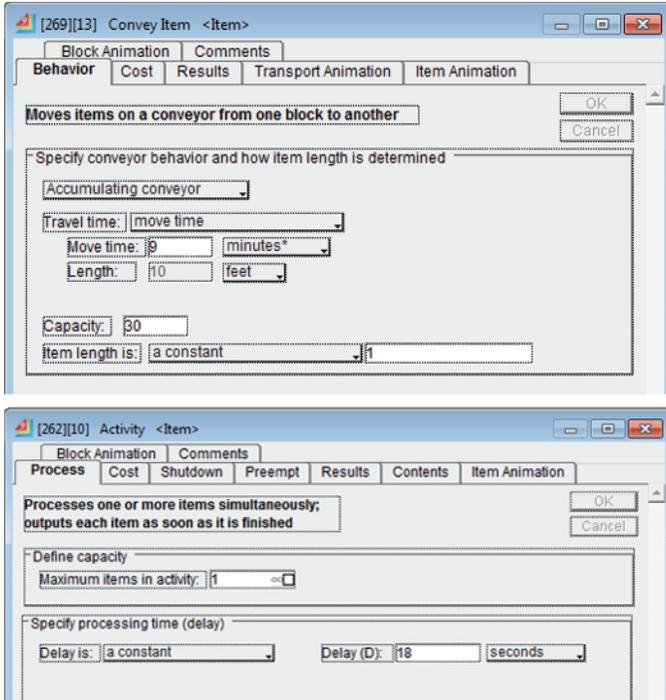


Figure 1.48. The 'Move time ... minutes*' attributes to clone into the 'Chairlifts' CONVEY ITEM blocks (above) and the (see figure 1.48 below): 'Delay (D) ... seconds' attributes to clone into the 'Seat distribution' ACTIVITY (below)

We should finally obtain dialog zones identical to the ones shown in Figure 1.49.

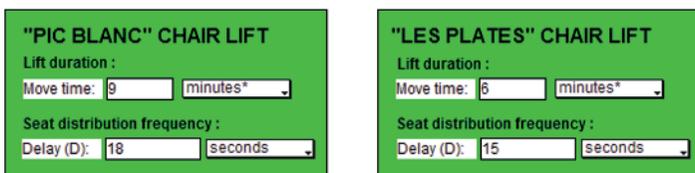


Figure 1.49. The two finished dialog zones

To create the buttons, we place two **BUTTON** blocks from the 'Utilities.lix' library in our model.

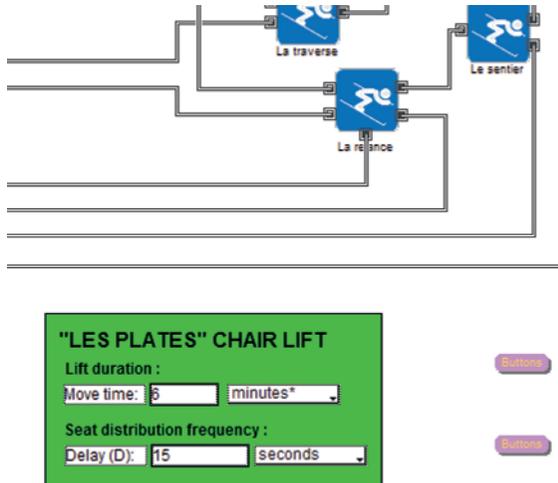


Figure 1.50. At bottom-right, our two **BUTTON** blocks

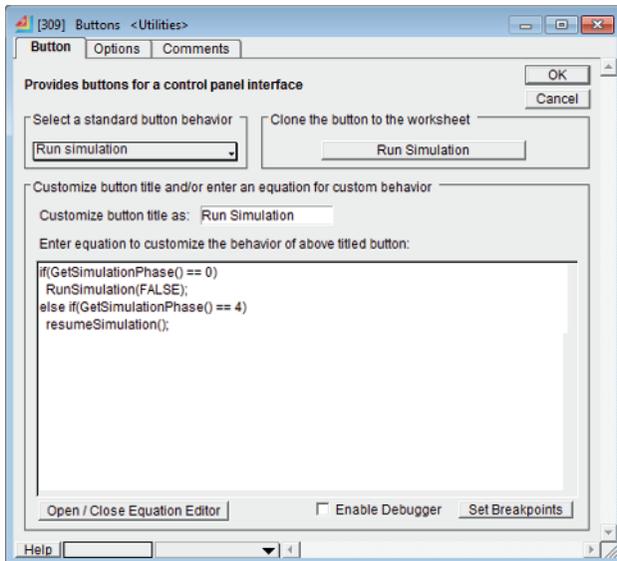


Figure 1.51. The configuration of the 'Run Simulation' button, with the choice of the button's action and the cloning zone

We configure the first with the RUN ANIMATION action and the second with the PAUSE SIMULATION action, then we clone each of the buttons (using the ‘Clone layer’ tool) into our model, taking care to place the clones over the BUTTON blocks to hide them.

Once finished, our model should resemble the one shown in Figure 1.52.

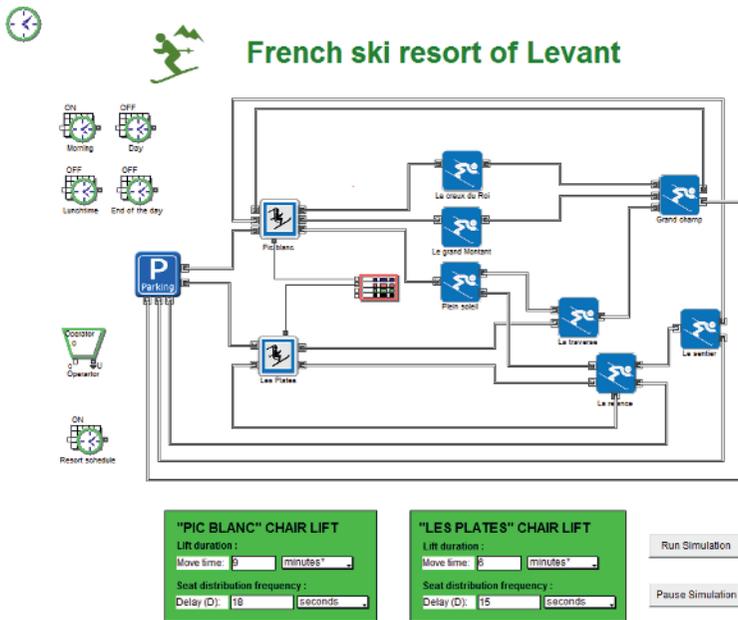


Figure 1.52. Our model with its two buttons (bottom right) which hide the blocks

Our model is now finished and we can run the simulation by clicking on the appropriate button, change the parameters of each of the chairlifts or pause the simulation.

1.4. Conclusion

ExtendSim offers a variety of functions that are not presented here, such as generating a 3D animation of a model, creating personalized blocks or manipulating databases using the Microsoft Excel *add-in*.

If you are interested and want to go beyond what has been presented in this chapter, you can study the software help and work through some of the examples provided.

A demonstration version of the ExtendSim software is available for download from the publisher's Website (see the Internet links at the end of the book).

Other, equally powerful, software exists, with several variations in use, functionalities and usability (see section 10.4 of Volume 1 of this book).

