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Deployment design and optimization of field hospitals

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Summary

In this work, through the analysis of the overall process and patient data of the field hospital, and at the same time make reasonable assumptions, the overall process simulation model of the field hospital is established by using the ExtendSim10 software, the simulation results are analyzed in combination with the problem description, the bottleneck problem is found and optimized based on the corresponding indicators, the improvement plan is designed, and the simulation results of the improvement plan are analyzed, and the analysis results show that the improvement plan can effectively improve the operation efficiency of the emergency department of the field hospital.

Keywords: modeling, simulation, data analysis, improvement scheme, ExtendSim10

Remote Operation Console Design for Disaster Relief Robots

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Abstract： By analyzing the overall process and patient data of the field hospital and making reasonable assumptions, this work establishes the overall process simulation model of the field hospital by using extendsim10 software, analyzes the simulation results in combination with the problem description, finds out the bottleneck problems, optimizes based on the corresponding indicators, designs and completes the improvement scheme, analyzes the simulation results of the improvement scheme, and the analysis results show that, The improvement plan can effectively improve the operation efficiency of emergency department in field hospital.

Key words: Modeling and simulation ExtendSim10 Data analysis Improvement plan

directory

1 Description of the current situation

Between September 6, 2017 and September 20, 2017, Hurricanes Irma and Maria struck Puerto Rico at the same time, severely affecting the local health care system. As of October 6 (one month after the first hurricane and two weeks after the second), only 25 of Puerto Rico's 68 hospitals were powered and functioning. Experts estimate that about 55 percent of Puerto Rico's 1.87 million residents have barely received any medical care two weeks after the last hurricane.

The Army Field Hospital is an ideal solution for responding to the needs of medical services after a hurricane, with full functionality, good mobility, adaptability to various climate changes, and strong self-support capabilities. Field hospitals are mostly modular in design, and if tents and related accessories are pre-positioned in hurricane-prone areas, they can be assembled and put into use within 24 hours. In order to be able to quickly admit a wide range of patients after a hurricane disaster in the future, the government wants to allocate field hospital resources to the relevant areas. However, before purchasing and deploying this resource on a large scale, the government needs to assess its healthcare service capacity in detail.

The current configuration of the field hospital consists of 12 tents for medical use and 2 tents reserved for medical staff accommodation and non-medical activities (free medical staff stay area).Off-Duty)。 At the entrance of the field hospital is a triage tent, which serves the functions of documentation, initial assessment and triage of patients, as well as a place for patients with acute and mild symptoms to receive treatment. There are a variety of other wards and areas in the hospital. The current layout of the field hospital and the number of beds in the individual tents. Administrators hope that field hospitals can admit 300-500 patients a day, with minimal care patients staying in the hospital for no more than 24 hours and intermediate care patients staying in the hospital for no more than 48 hours. As soon as beds become available in a nearby well-functioning hospital, all patients except for pregnant women (L&D) will be brought to the hospital for treatment as soon as possible. Pregnant women and newborns are discharged from the hospital as soon as possible after recovery. All units in the field hospital are equipped with environmental control units (ECUs) such as air conditioning to ensure that patients can be admitted at full capacity and ensure their comfort and well-being.

2 Problem description and preliminary analysis

From the perspective of an expert from a consulting firm, the simulation method was used to simulate and analyze the operation of the field hospital using the existing data and layout, and answer the questions in the two phases. In the pre-project study, there are the following data:

1、Post-disaster patient arrival rate and their medical needs

2、The time required for multiple treatment sessions

3、Elements of operational management of a field hospital

In addition, reasonable assumptions are made and modeled and simulated based on the information that is not provided.

The specific issues of the two phases are as follows:

Phase 1: Current operations of the field hospital

The goal of the first phase was to build a simulation model of a field hospital and answer the following questions based on the simulation results:

1. Is the current configuration of the field hospital adequate to handle the expected patient load? If not, give a reason.

Preliminary analysis: Determine the load based on the modeled cohort, where the patient is waiting for congestion, and the average time the patient passes through each tent. If the load is too large, analyze the relevant causes.

2. What are the current bottlenecks in field hospitals? (Staffing, layout, equipment, and any other perceived bottlenecks can be considered)

Preliminary analysis: The bottleneck of the field hospital can be understood as the problem that makes the field hospital unable to meet the current patient load. Firstly, the tent with bottlenecks was found through the average passing time, and then the statistical module was used to count various data of each queue, activity, and patient flow, and the data were analyzed and sorted to find out where the bottlenecks were.

3. How will bottlenecks be addressed to improve field hospital operations? (Consider changing staffing, layout, equipment, and any other perceived bottlenecks, etc.)

Preliminary analysis: In the previous question, we have found out the bottlenecks in field hospitals based on statistical data, analyzed and improved them based on the existing bottlenecks, and found out the appropriate optimization plan. In addition to existing bottlenecks, reasonable further optimization and improvement, including staffing and facility placement, will be made in a way that does not increase costs.

4. If there is an overcapacity in hospitals, how will the hospital configuration be changed and the number of resources will be reduced?

Preliminary analysis: overcapacity is reflected in the existence of personnel and equipment with low utilization, and it is enough to improve and optimize this phenomenon.

5. Select indicators that are considered representative of the performance of the field hospital and evaluate them.

Preliminary analysis: The evaluation index of the field hospital is easily affected by the number of patients arriving and the probability of various diseases, in order to minimize the error, the passage time of each tent should be counted separately and then added one by one, which can largely exclude the influence of random factors and can accurately reflect the degree of improvement of the current performance compared with the previous one

Phase 2: Future operations of the field hospital

In order to meet future post-disaster medical needs, the second phase aims to use simulation to evaluate two or more field hospital improvements (the first phase model can be modified or a new simulation model can be established). For each improvement scenario, answer the following two questions based on the simulation results:

1. How did the programme improve the corresponding performance indicators (those selected in the first phase of evaluation) for field hospitals?

Preliminary analysis: According to the requirements of the topic, two improvement plans for the field hospital model were formulated, and the improvement results were evaluated according to the performance indicators formulated above, and the better one was selected as the final optimization plan.

2. If other disasters occur in the future, such as earthquakes, will improved field hospitals provide adequate support for post-disaster medical care?

Preliminary analysis: According to the data, the general natural earthquake disaster refers to the earthquake disaster that causes 50~300 deaths or major economic losses, and the direct economic loss of the earthquake does not exceed 1% of the GDP of the province (autonomous region and municipality directly under the Central Government) in the previous year; Earthquake disasters caused by earthquakes of magnitude 6.5~7.0 that occur in densely populated areas. According to the situation of the natural disaster, the results can be simulated by modifying the different disease probabilities of patients in the model, and judging whether the post-disaster medical problems can be met according to the degree of change in the performance indicators.

3. Research Methods and Model-Building Process

3.1 Overall Approach and Design

3.11 Patient arrival data analysis

(1) Stationarity test

The maximum capacity of the hospital was 500 combined with the proportion of patients arriving to obtain the number of arrivals per hour, and the SPSS software was used to perform one-way ANOVA for the number of arrivals in these 168 hours

First, the mean of the number of arrivals per day is approximately equal, which means that one-way ANOVA can be performed.

Then, observing the ANOVA table, the significance is equal to 1, which proves that the number of days has no effect on the number of arrivals per hour, which means that the data is roughly stable, and then shows that all the data can be fitted to a statistical distribution for simulation experiments.

单向

[数据集1]

描述

人数

		N	均值	标准差	标准误	均值的 95% 置信区间		极小值	极大值	分量间方差
						下限	上限			
1		24	21.33	5.130	1.047	19.17	23.50	14	31	
2		24	21.38	5.555	1.134	19.03	23.72	11	31	
3		24	21.29	8.073	1.648	17.88	24.70	8	33	
4		24	21.38	7.137	1.457	18.36	24.39	4	31	
5		24	21.29	10.593	2.162	16.82	25.76	4	35	
6		24	21.29	9.585	1.956	17.24	25.34	6	40	
7		24	21.29	9.724	1.985	17.19	25.40	4	33	
总数		168	21.32	8.062	.622	20.09	22.55	4	40	
模型	固定效应			8.211	.633	20.07	22.57			
	随机效应				.633[a]	19.77[a]	22.87[a]			-2.808

a. 警告：分量间方差为负。在计算该随机效应度量时，该方差将被替换为 0.0。

方差齐性检验

人数

Levene 统计量	df1	df2	显著性
6.179	6	161	.000

ANOVA

人数

	平方和	df	均方	F	显著性
组间	.226	6	.038	.001	1.000
组内	10854.417	161	67.419		
总数	10854.643	167			

Figure 1: ANOVA table

The Stat:Fit software was used to test the independence and homogeneity of the data, and if the above tests were passed, the data could continue to be distributed and fitted.

Convert the number of arrivals per hour into patient arrival interval data and import it into Stat:Fit

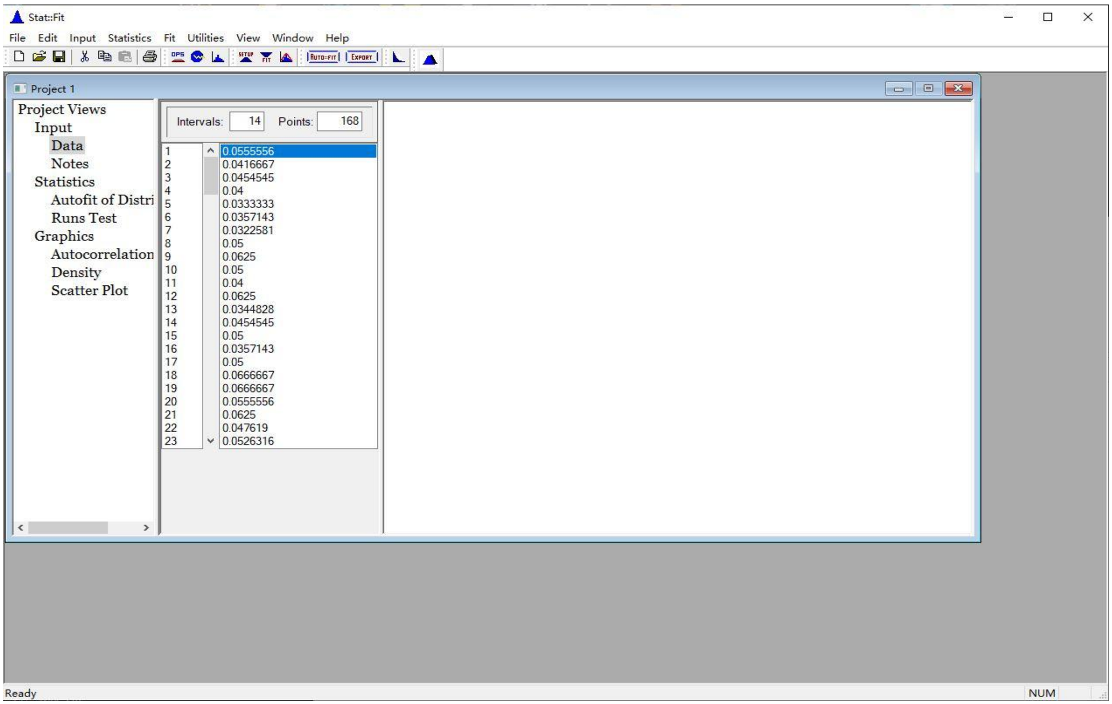


Figure 2: Stat:Fit software

(2) Independence test:

The scatter plot appears scattered and untrended, indicating that the data is independent

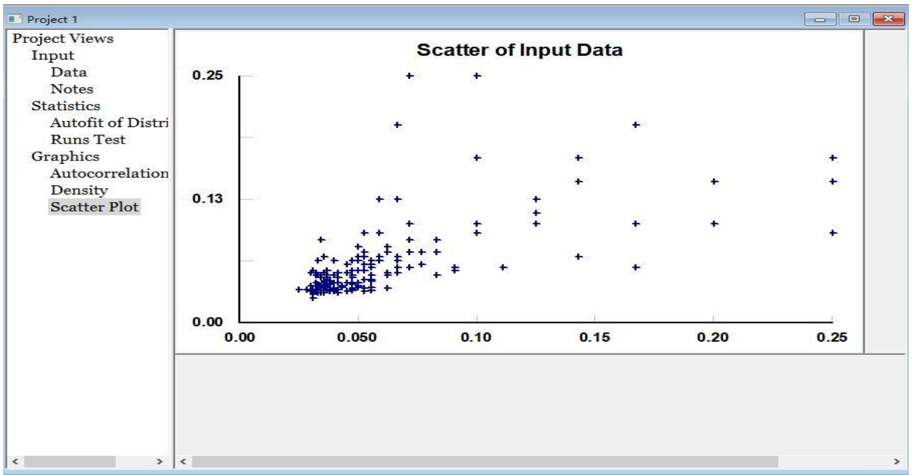


Figure 3: Scatter plot

Autocorrelation Diagram From the graph, it can be seen that all correlation coefficients are approximately close to 0, so the data are independent.

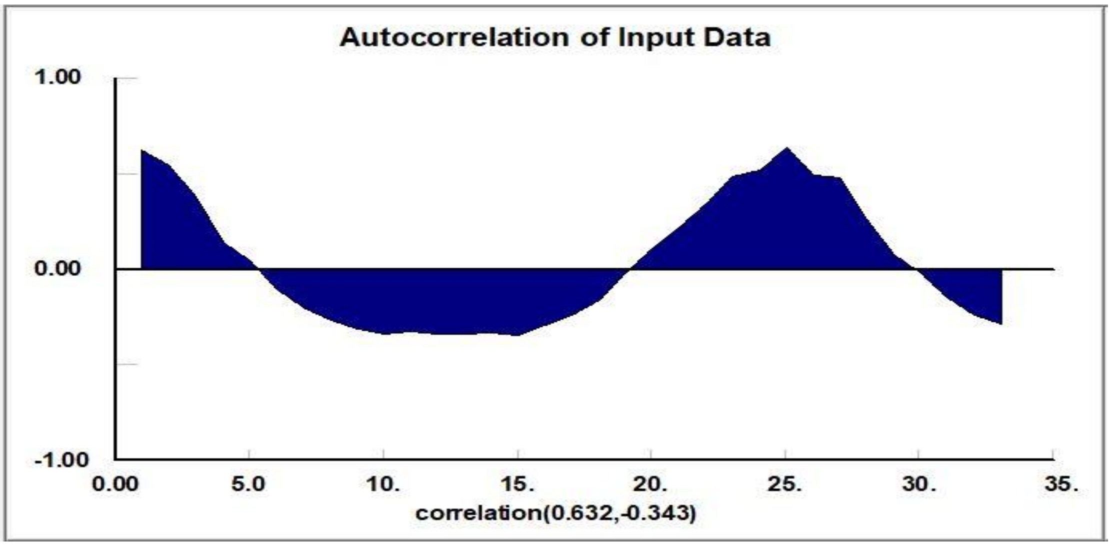


Figure 4: Autocorrelation plot

Trend Segment Test WHERE THE MEDIAN TEST RESULT IS REJECT, and the turning point test result is DO NOT REJECT, although the median test result is not passed, but combined with the above independence test and the turning point test, the data independence has been strongly proved, so the median test result can be ignored, that is, the data can be considered to pass the trend segment test and have independence.

runs test on input

runs test (above/below median)

data points	168
points above median	75
points below median	83
total runs	25
mean runs	79.7975
standard deviation runs	6.24869
runs statistic	8.76943
level of significance	0.05
runs statistic(0.025)	1.95996
p-value	0
result	REJECT

runs test (turning points)

data points	151
turning points	93
mean turnings	100.333
standard deviation turnings	5.14997
turnings statistic	1.42396
level of significance	0.05
turnings statistic(0.025)	1.95996
p-value	0.154459
result	DO NOT REJECT

Figure 5: Test rendering results

(3) Homogeneity test:

A histogram of data frequency, in which there is only one peak value of data frequency, it means that the data matches the same statistical distribution.

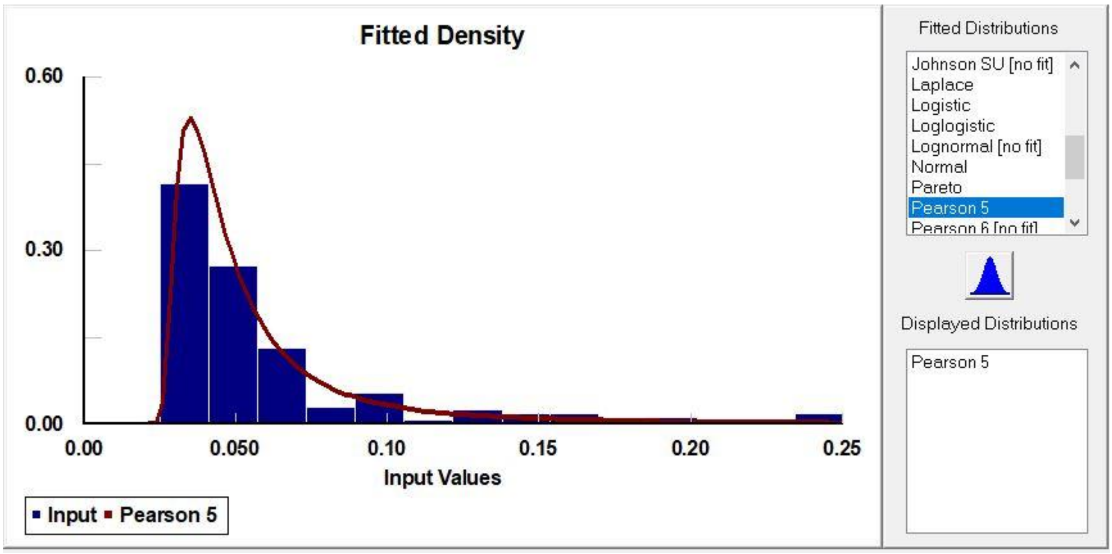


Figure 6: Histogram of data frequency

(4) Automatic fitting

The automatic fitting results show that the PearsonV distribution is the one that best matches the data

autofit of distributions

distribution	rank	acceptance
Pearson 5(0.0213, 2.01, 0.041)	100	do not reject
Inverse Gaussian(0.023, 0.0344, 0.037)	40.4	do not reject
Loglogistic(0.025, 1.89, 0.0211)	32	do not reject
Weibull(0.025, 1, 0.035)	0.0228	reject
Exponential(0.025, 0.0349)	0.0227	reject
Beta(0.025, 0.25, 1.09, 6.23)	0.00507	reject
Extreme Value IB(0.0848, 0.0646)	0	reject
Normal(0.0599, 0.0415)	0	reject
Logistic(0.0517, 0.0177)	0	reject
Rayleigh(0.00288, 0.0499)	0	reject
Triangular(0.0238, 0.255, 0.0303)	0	reject
Pareto(0.025, 1.37)	0	reject
Cauchy(0.042, 0.0105)	0	reject
Uniform(0.025, 0.25)	0	reject
Extreme Value IA(0.0452, 0.0204)	0	reject
Chi Squared(0.025, 0.47)	0	reject
Laplace(0.0476, 0.0238)	0	reject
Power Function(0.0249, 0.27, 0.411)	0	reject
Erlang	no fit	reject
Gamma	no fit	reject
Johnson SB	bad test	reject
Lognormal	no fit	reject
Inverse Weibull	no fit	reject
Johnson SU	no fit	reject
Pearson 6	no fit	reject

Figure 7: Auto-fit results

(5) Summary

The stationarity test, independence analysis and homogeneity test were carried out by using SPSS software and Stat:Fit software, and finally the distribution of patient interval arrival time data was obtained, Pearson 5, and the results were finally applied to ExtendSim10 software as the distribution of patient arrival data.

3.12 Patient Arrival Method

(1) Reasonable assumptions

The patient arrives on foot, which indicates that the patient is mobile, which is reflected in the modeling system as if a medical escort is required or whether he or she can go to the office independently.

(2) Distribution fitting

As you can see, the initial data in the table shows the proportion of days of arrival by way of arrival, ranging from 65% to 83% walking from day 1 to day 7

到达方式		
Day 1	80% 步行	
Day 2	65% 步行	
Day 3	78% 步行	
Day 4	83% 步行	
Day 5	71% 步行	
Day 6	70% 步行	
Day 7	75% 步行	

Figure 8: The proportion of people walking by the means of arrival corresponding to the number of days

Fit the data in Figure 1 and set a Trianqular distribution to fit, with a maximum value of 083, the minimum value is set to 0.65, and the mode is set to 0.75, and the most similar distribution is obtained

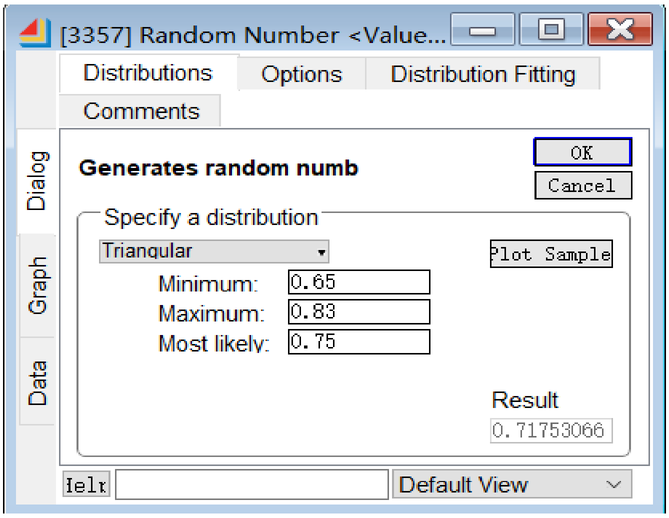


Figure 9: Distribution fitting

(3) Attribute settings

A module is established in the model to determine how the patient moves, and Figure 10 represents a schematic diagram of how the patient moves in the model.

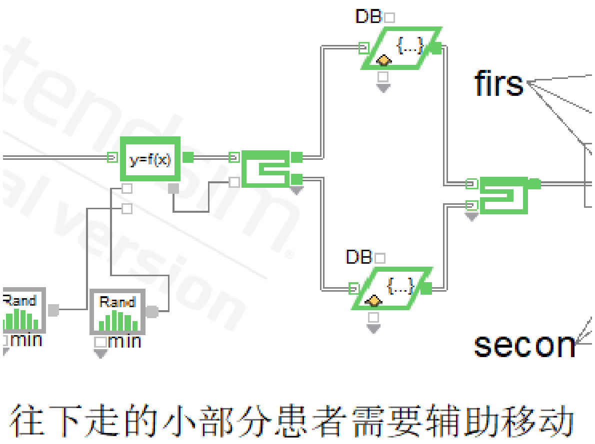


Figure 10: Determining how the patient moves the module in the model

As the patient passes through the portal, a random number of 0-1 is output and compared to the size of the distribution above. If the distribution size is greater than the above, the patient is incapacitated, and the value of this attribute is set to each entity to facilitate subsequent triage. Figure 11 shows the specific random value setting to determine whether a patient is incapacitated

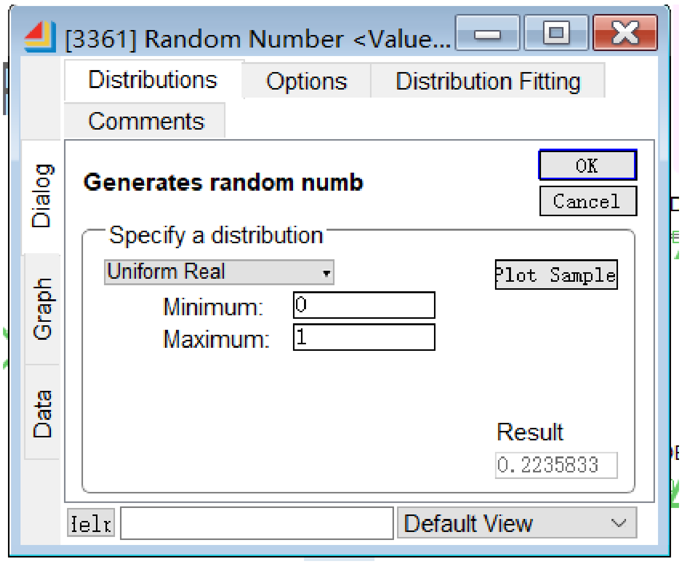


Figure 11: The specific settings for random numbers

Establish the programming logic in the equation, when inCon0 is less than inCon1, output 1 otherwise output 0.

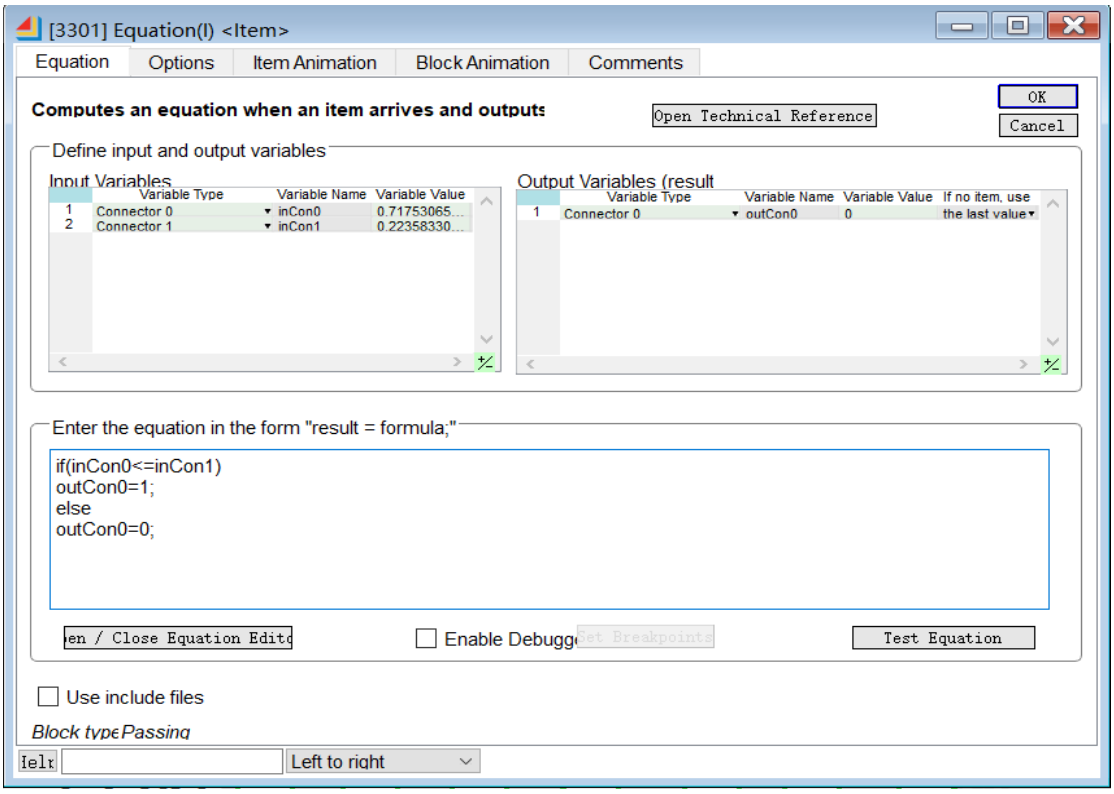


Figure 12: Eqaution determines the specific output value

Finally set the property moving abililty

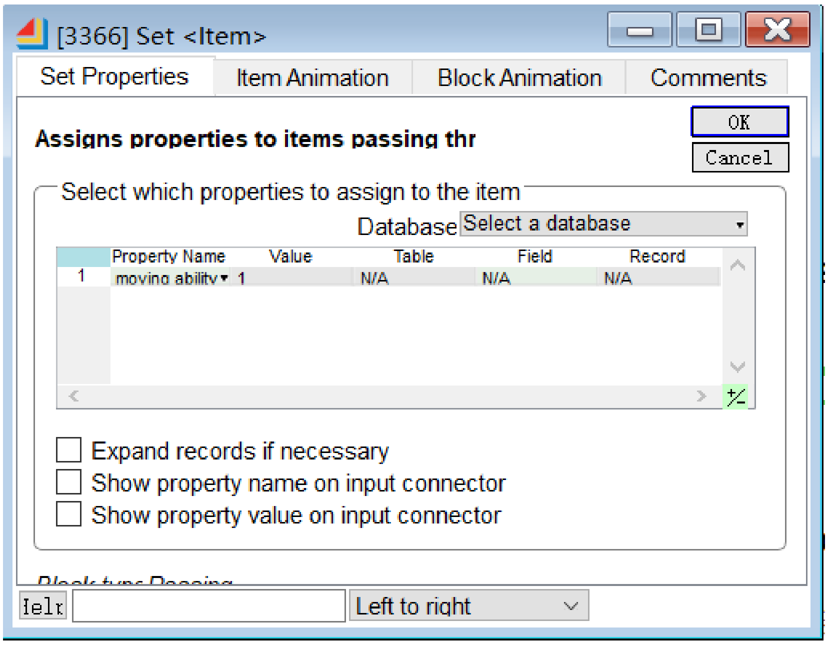


Figure 13: Setting the property moving abililty

(4) Patient triage design

When the patient leaves the triage tent for triage, the patient will choose a different path by judging whether the patient is mobile, and if the patient is mobile, the patient does not need to obtain the resource of an escort, and can go to the office alone, reducing the resource occupation. The schematic diagram of the model module is shown in Figure 14:

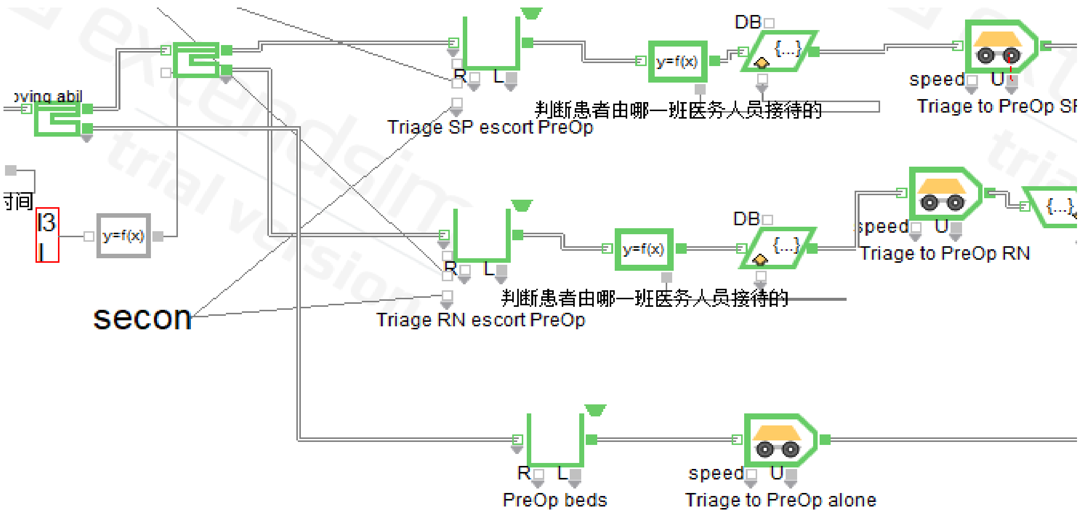


Figure 14: Schematic diagram of the shunt design module

If you have the ability to move and take the lowest route during the diversion, there is no need to occupy transportation resources. Figure 15 shows the specific settings.

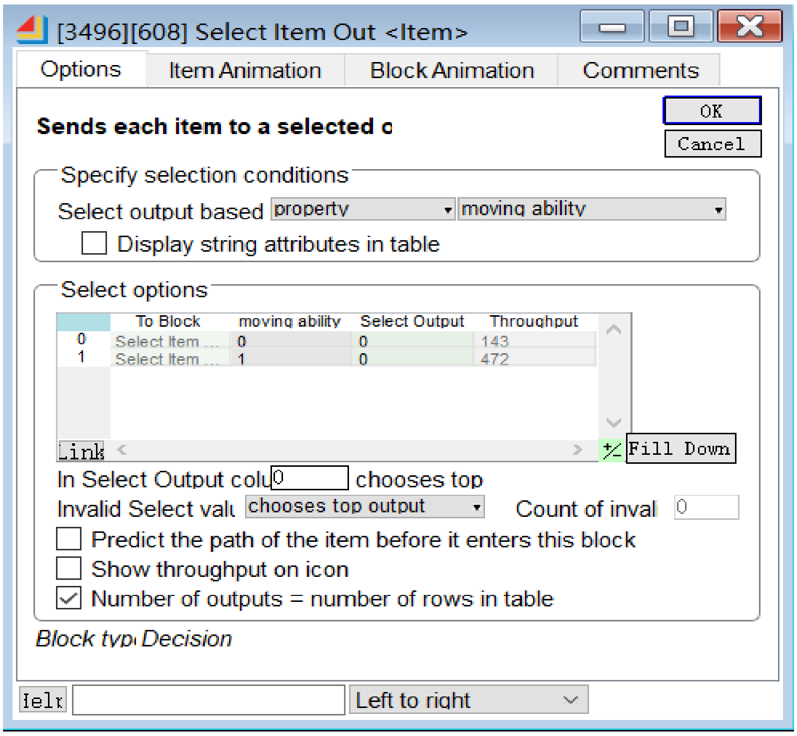


Figure 15: Shunt output setup

3.13 Assumptions about the initial layout of hospital facilities and the speed of patient movement

(1) Initial layout settings

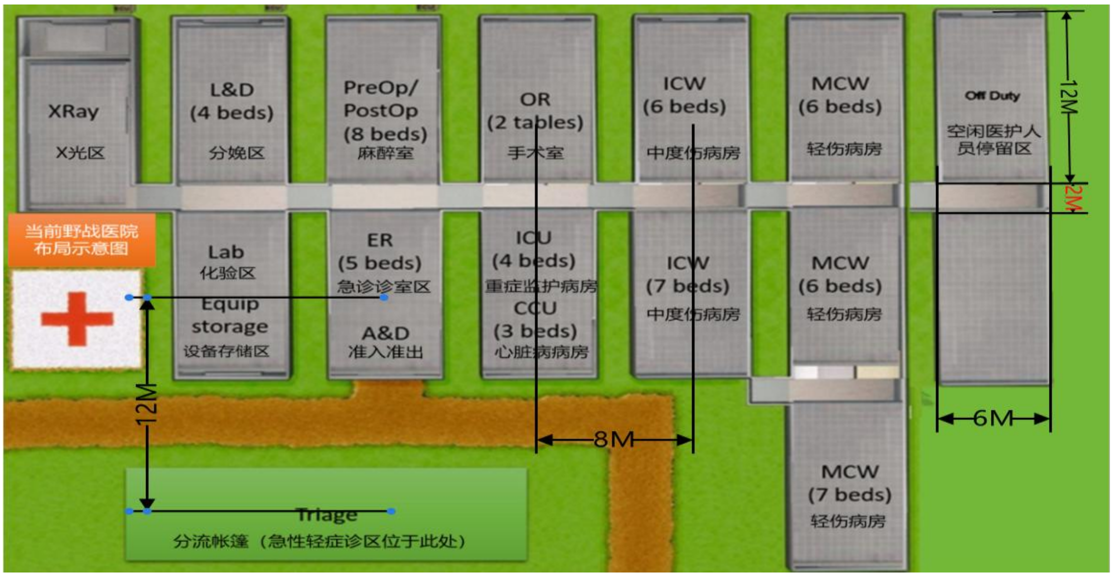


Figure 16: Initial layout drawing

and (2) patient movement speed assumptions

According to the relevant reference materials, the field hospital tent is generally 12m long and 6m wide, and the floor plan data is drawn as a reference for the transportation distance, and the patient's movement speed is half of the average human movement speed as a reference, that is, 0.6m/s, and Figure 17 is the specific setting of the patient's movement speed.

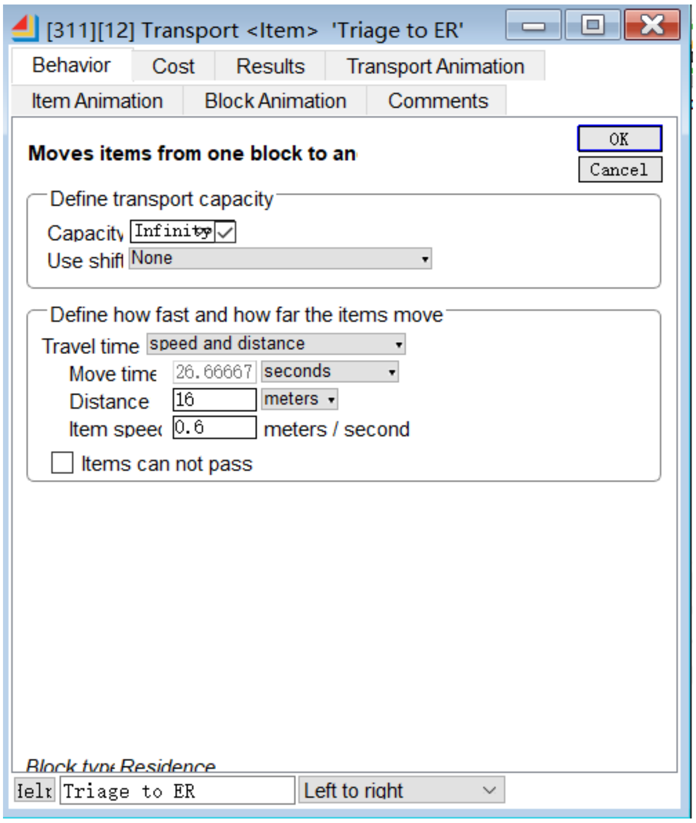


Figure 17: Specific settings for patient movement speed

3.14 Hospital Resource Allocation

The following is the specific situation of staffing, which is divided into two shifts according to the number of people given in the question, and each class is named according to different clinics, with the name of the clinic + the type of staff as the naming standard. The initial headcount setting is above the resource, and the utilization rate is below the resource. Equipment, including beds and X-ray equipment, is a non-allocating resource.

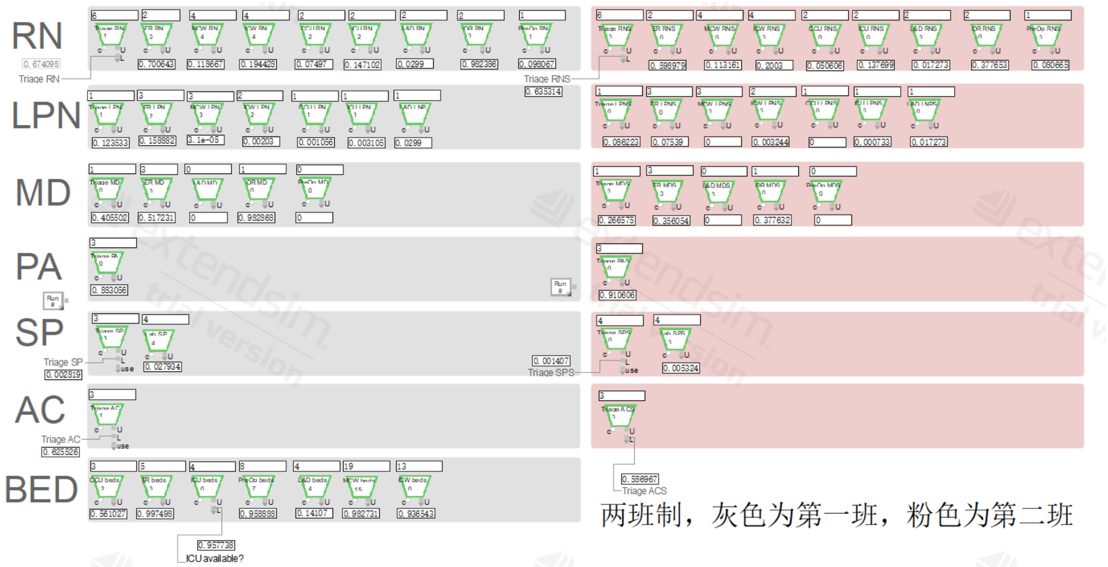


Figure 18: Staffing specifics

Laboratory technicians, surgeons, and X-ray personnel are all non-allocable resources, and the fixed resource is named as the type of staff

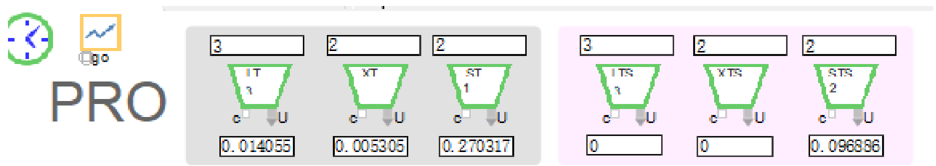


Figure 19: Non-allocable and fixed resources

3.15 Scheduling Module

(1) Shift time control switch module

The time control module is shown in Figure 20

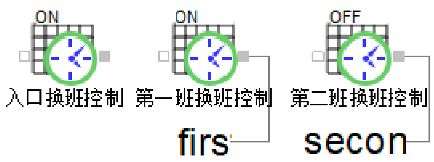


Figure 20: Time control module

Use the shift module to schedule shifts, the initial shift is divided into two shifts, each shift has the same number of people and changes shifts once every 12 hours, the right end leads to the variables first and second, when the module is on the state, the output is 1 when the staff of the shift is on duty, otherwise it is 0. Shifts are rotated every 24 hours. The specific two-shift shift module setting diagram is shown in Figure 21 and Figure 22

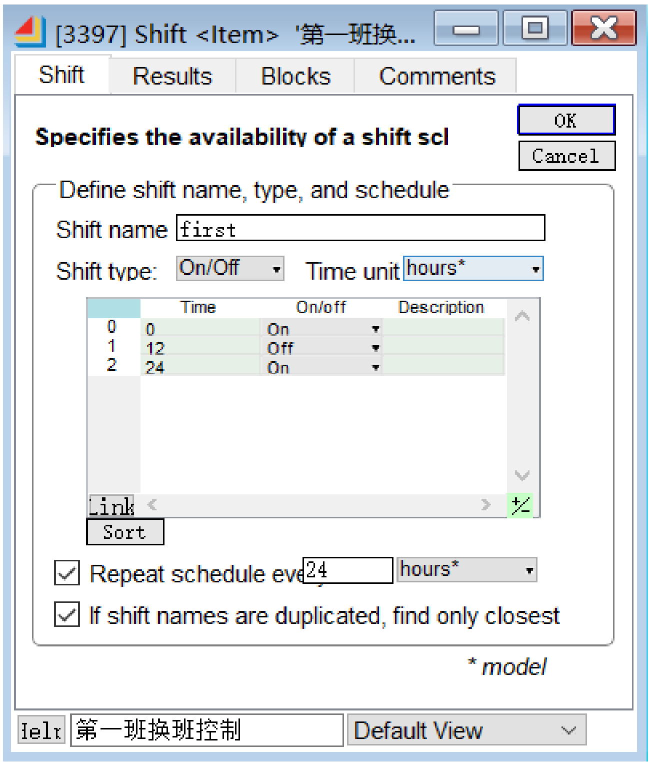


Figure 21: First shift shift control

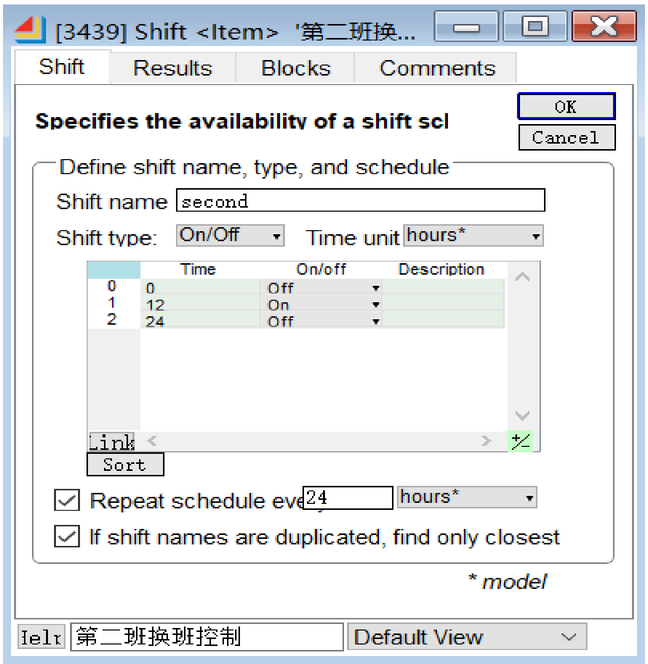


Figure 22: Second shift shift control

Resource pools are enabled by referencing shifts by using the shift attribute

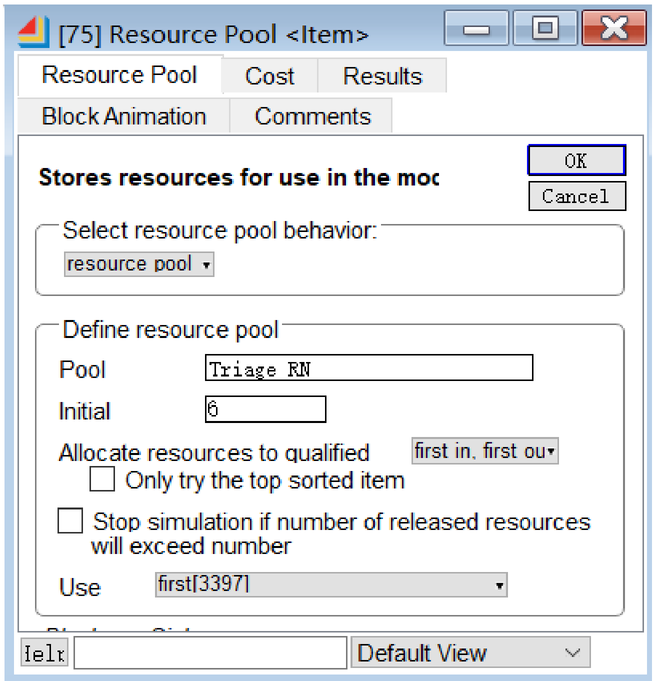


Figure 23: Resource pool settings for Triage RN

(2) Waiting for the entrance to change shifts

The module consists of inputs, queues, and gates, as shown in Figure 24.

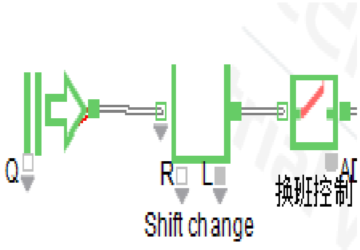


Figure 24: Waiting for a shift change at the entrance

Based on the floor plan given in the question and the general speed of human movement, it is estimated that the shift change will take at least one minute, during which the hospital will be closed and will not accept new patients, and the activities and transports that are already in progress will not be suspended, but the new patients will need to queue at the door to wait for the shift to end. Figure 25 shows the door of the Shift association type, and Figure 26 shows the specific shift setting.

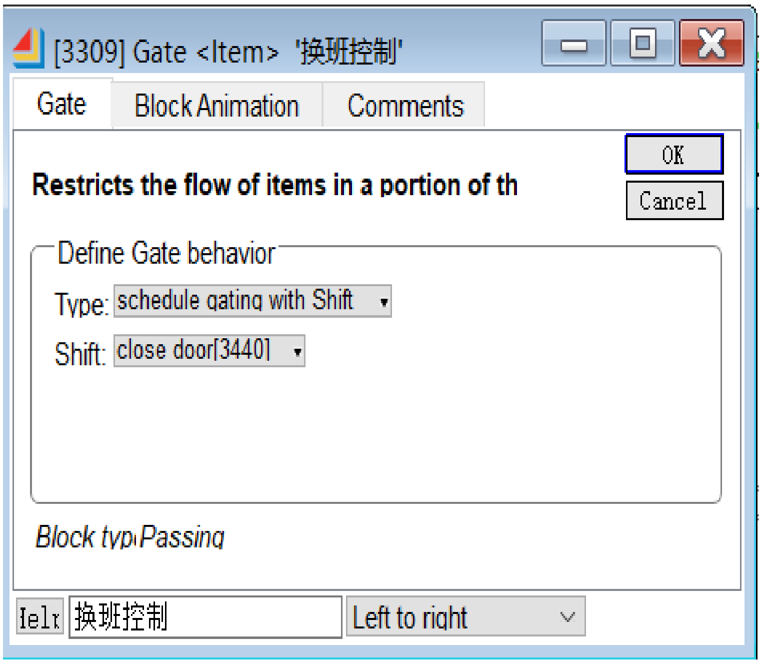


Figure 25: Shift association type gates

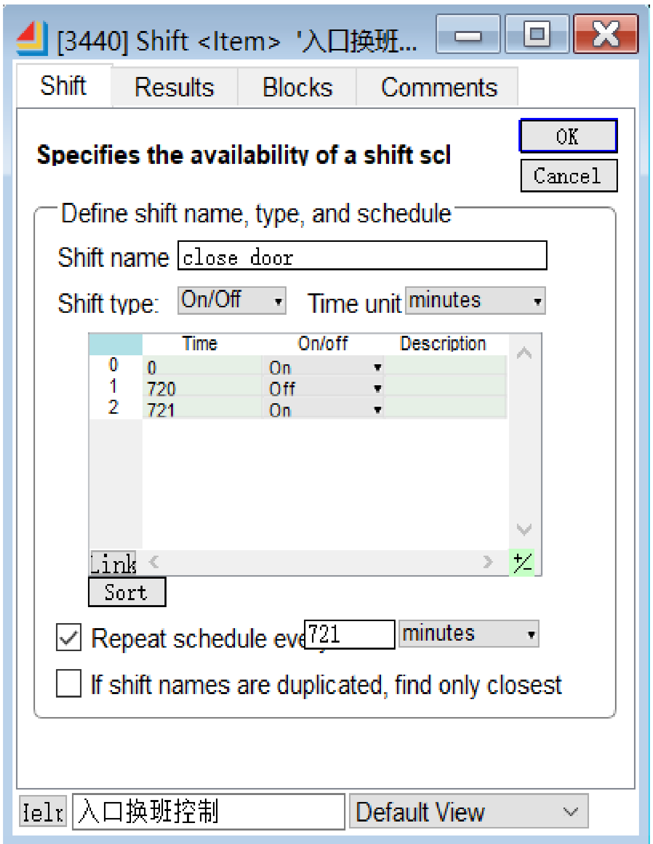


Figure 26: The specific shift settings

(3) Queue resource demand and resource release control

队列资源需求控制受到排班的影响，分为两种情况 All resource are required 和 Take from any。

All resource are required 的情况

The number of resources required is controlled through the above-mentioned elicited variables first and second, if it is the shift on duty, the output of the corresponding variable is 1, that is, the value received by the input port of the queue is 1, that is, one such resource is needed, and conversely, if it is in the off duty state, the output of the corresponding variable is 0, that is, zero such resources are needed, so as to realize that there will be no resource demand and release confusion when different shifts are in shifts。

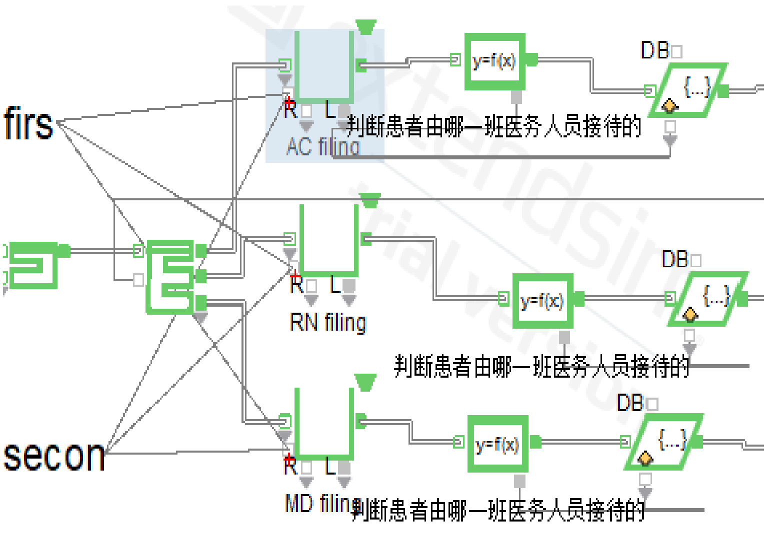


Figure 27: Schematic diagram of the resource requirement control module

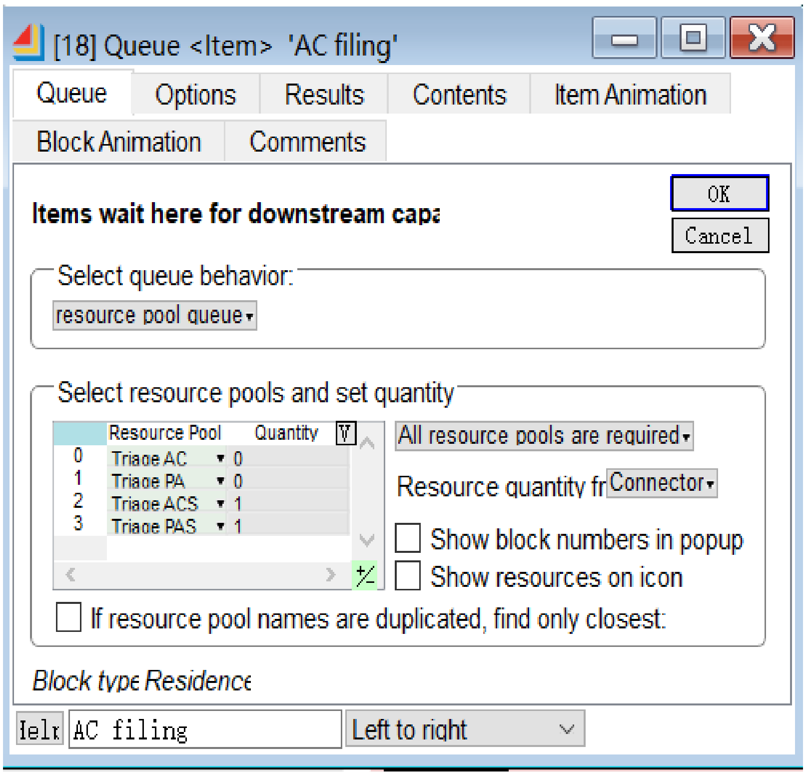


Figure 28: Schematic diagram of the queue module for resource requirements

Figure 29 shows the schematic diagram of resource release control.

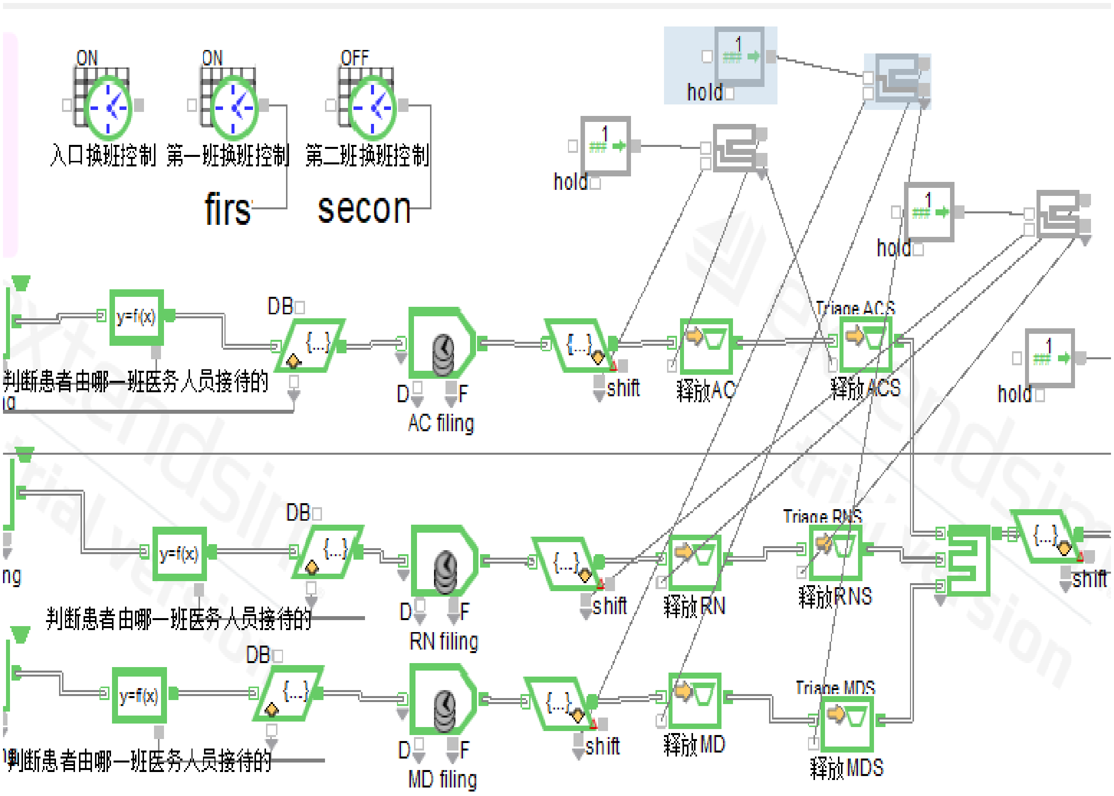


Figure 29: Schematic diagram of resource release control

First, obtain the current time through equation to divide 12 to interpret whether it is odd or even, and input the result to set to set an attribute that indicates which shift of staff is receiving patients, and then input this attribute into the select value out module to control the specific number of resources released, if it is the first shift to receive patients, the resource release input of the first shift is 1, otherwise it is 0, The same goes for the second class. Figures 30 to 33 are the specific settings in the module

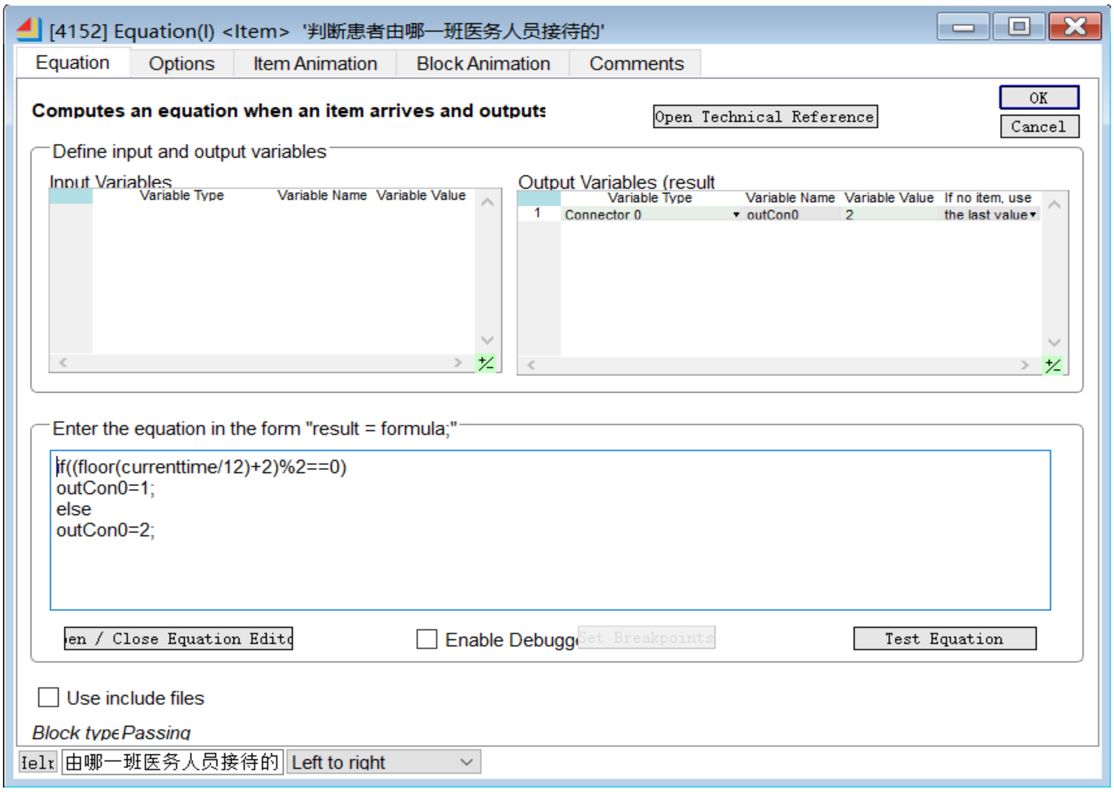


Figure 30: Specific equations

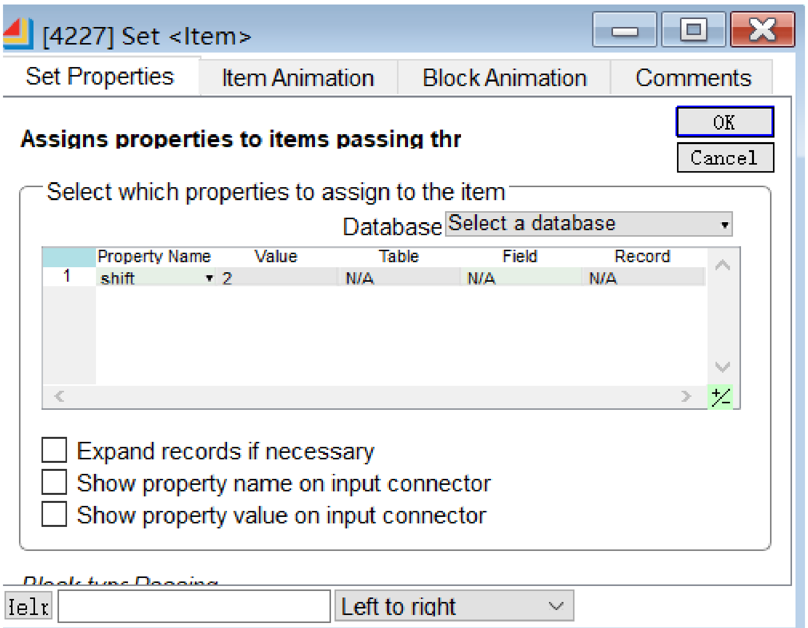


Figure 31: Set the property to record a specific reception shift

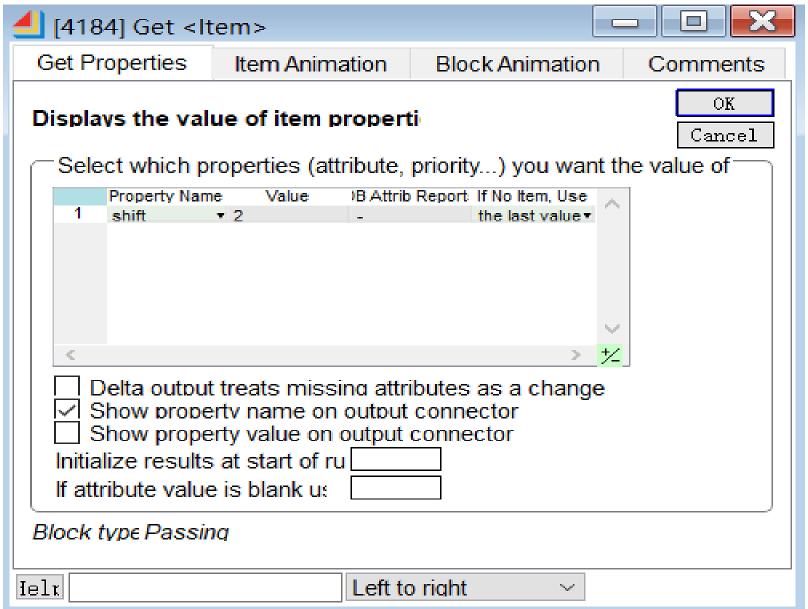


Figure 32: Obtaining attributes to determine which class of resources to release

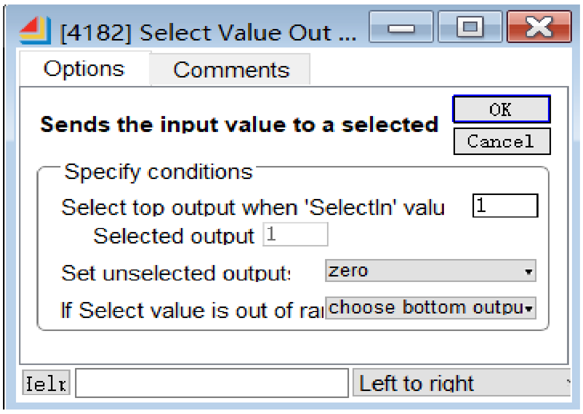


Figure 33: In the first shift, the first interface outputs 1, the second interface outputs 0, and vice versa

Take from any resource 的情况

图 34 为 Take from any resource 时的模型示意图：

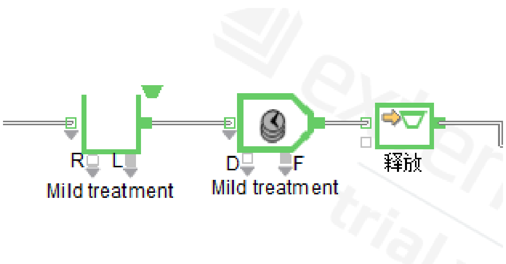


图 34：Take from any resource 模型示意图

This situation is much simpler, if it is not on duty in the shift, the number of available resources in this shift will automatically return to 0, that is, the queue will not consider the resources in the off duty when obtaining resources, and the name of the resource obtained by the queue is recorded on the property, and only the corresponding attribute can be released when it is released, Figure 35 to 37 is the specific setting interface.

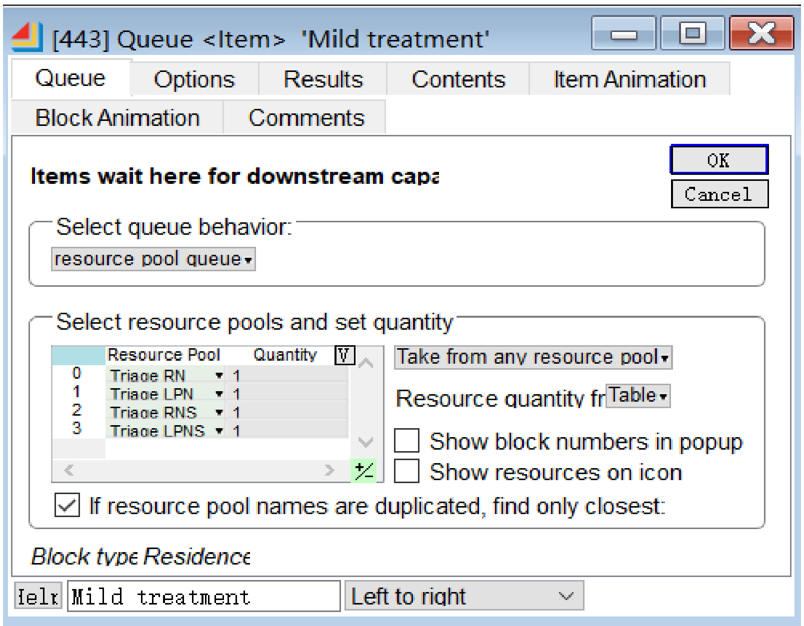


Figure 35: Schematic diagram of the queue module for resources

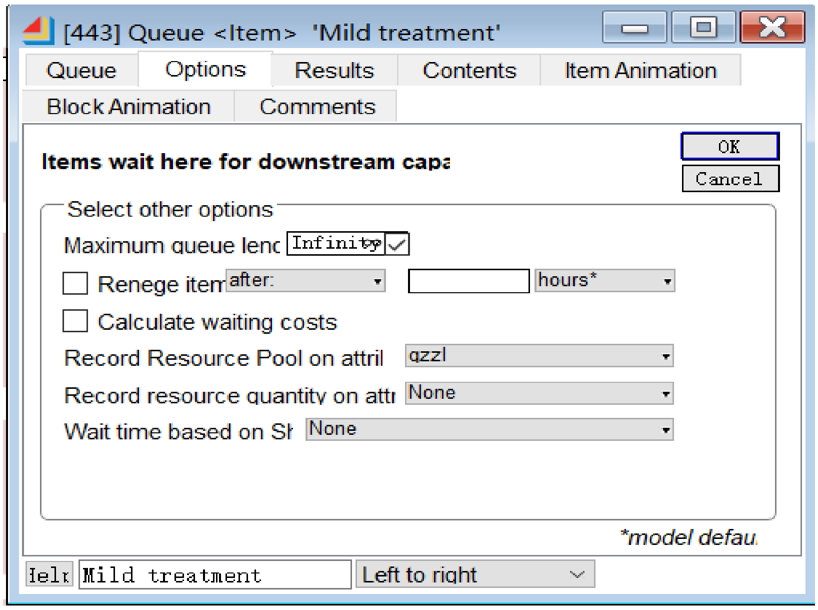


Figure 36: Record the name of the retrieved resource on the qzzl attribute

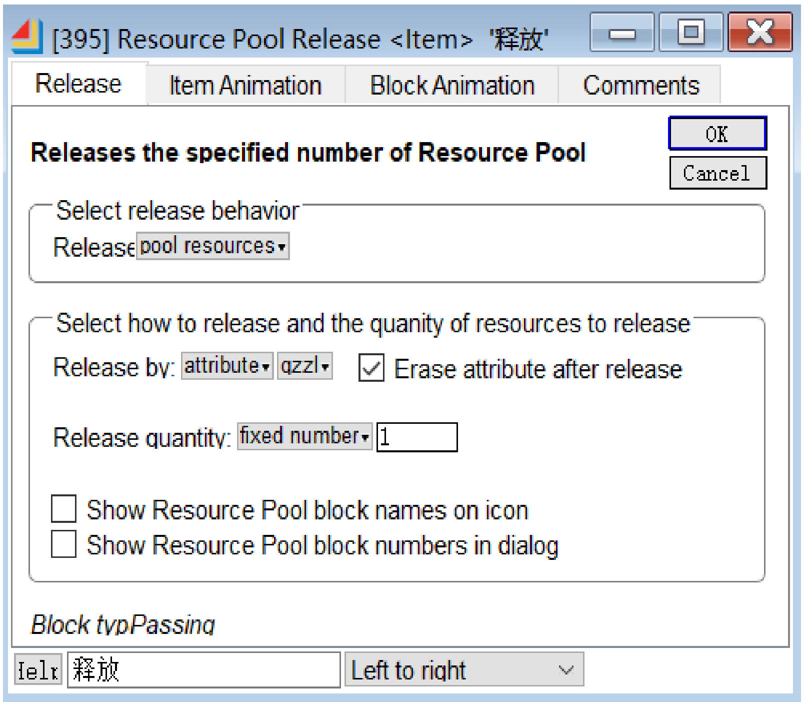


Figure 37: When releasing resources, you can also release them according to the name of this attribute

(4) Information input judgment

Since there are many branches in the process that need to be judged by the information provided by the resource pool, if different shifts are carried out by different shifts, that is, when different resource pools are used in turn, it is necessary to consider the variables that provide information according to the shift replacement, and the control input can be realized through the first and second variables mentioned above, and if the first shift is on duty, that is, the first output is 1, then the output of the following variables is used, and vice versa. The modules and their specific settings are shown in Figures 38 to 40

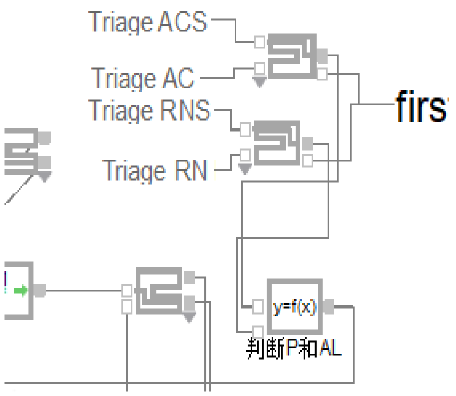


Figure 38: Information input judgment module

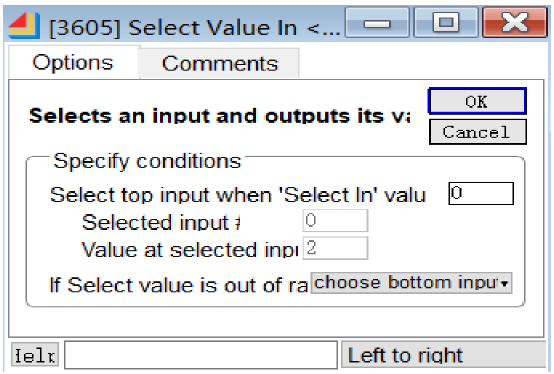


Figure 39: Specific control logic

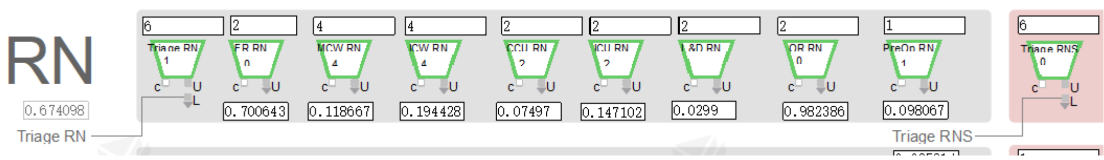


Figure 40: Information flows from the first and second shifts, respectively.

3.2 Model building process

3.21 Establishment of the general model

Based on the above research methods and some reasonable assumptions, a modeling model of the entire field hospital was finally established, as shown in Figure 41:

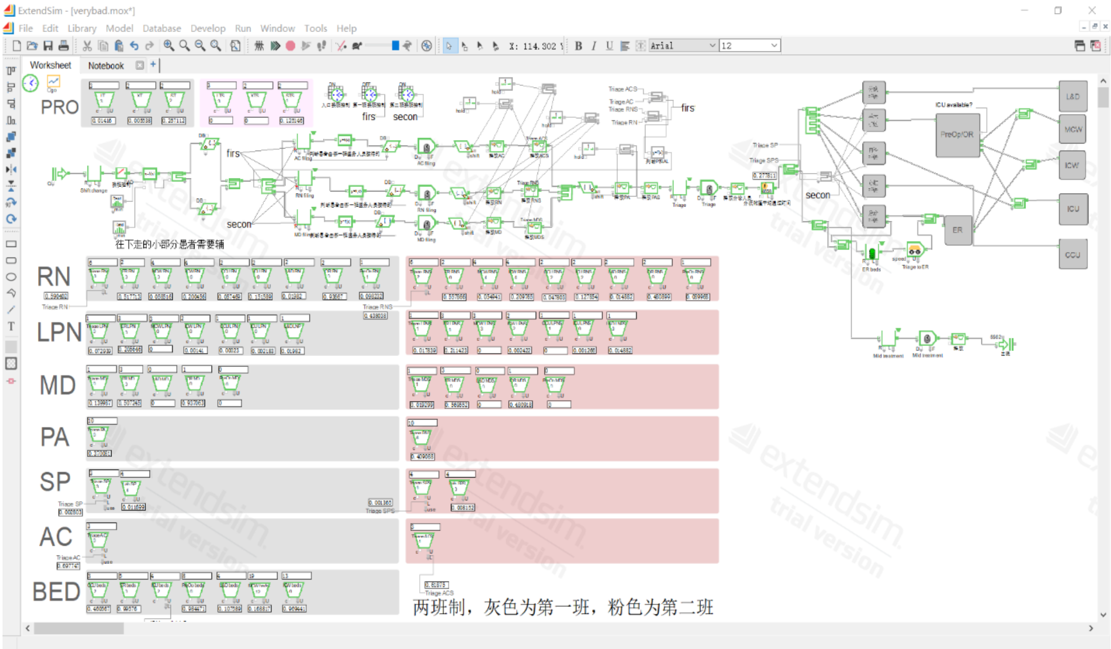


Figure 41: All modules and resources of the field hospital

3.22 Triage tents and file triage

In terms of large partitions, the triage tent can be divided into two areas: filing and triage

(1) Filing area

Figure 42 shows the modules in the filing area.

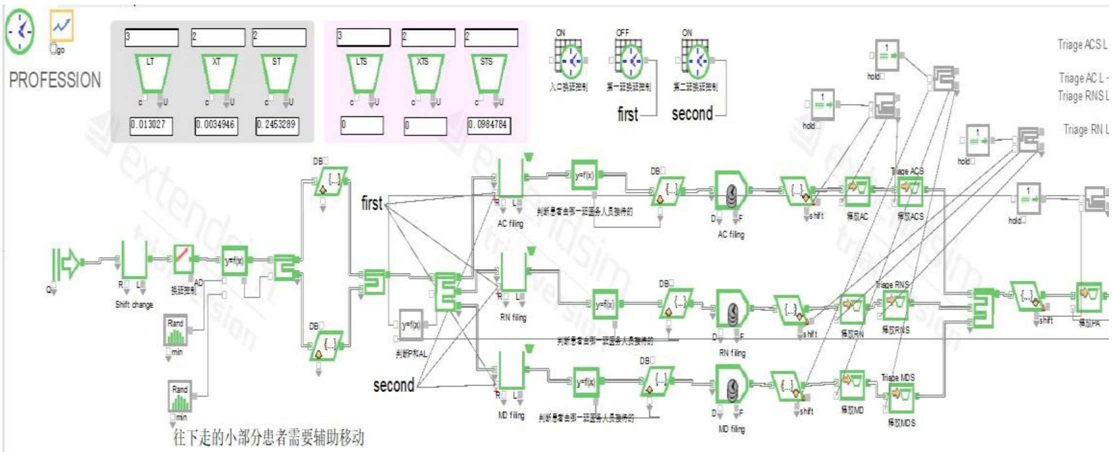


Figure 42: Filing Area Module

The logic is that AC is the main person, RN and MD are the alternative personnel, the specific model diagram is shown in Figure 43, and the specific code is shown in Figure 44

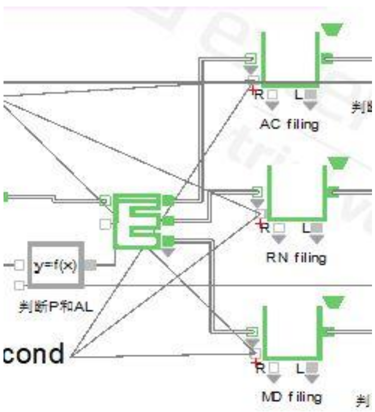


Figure 43: Determine the resource module required by the patient

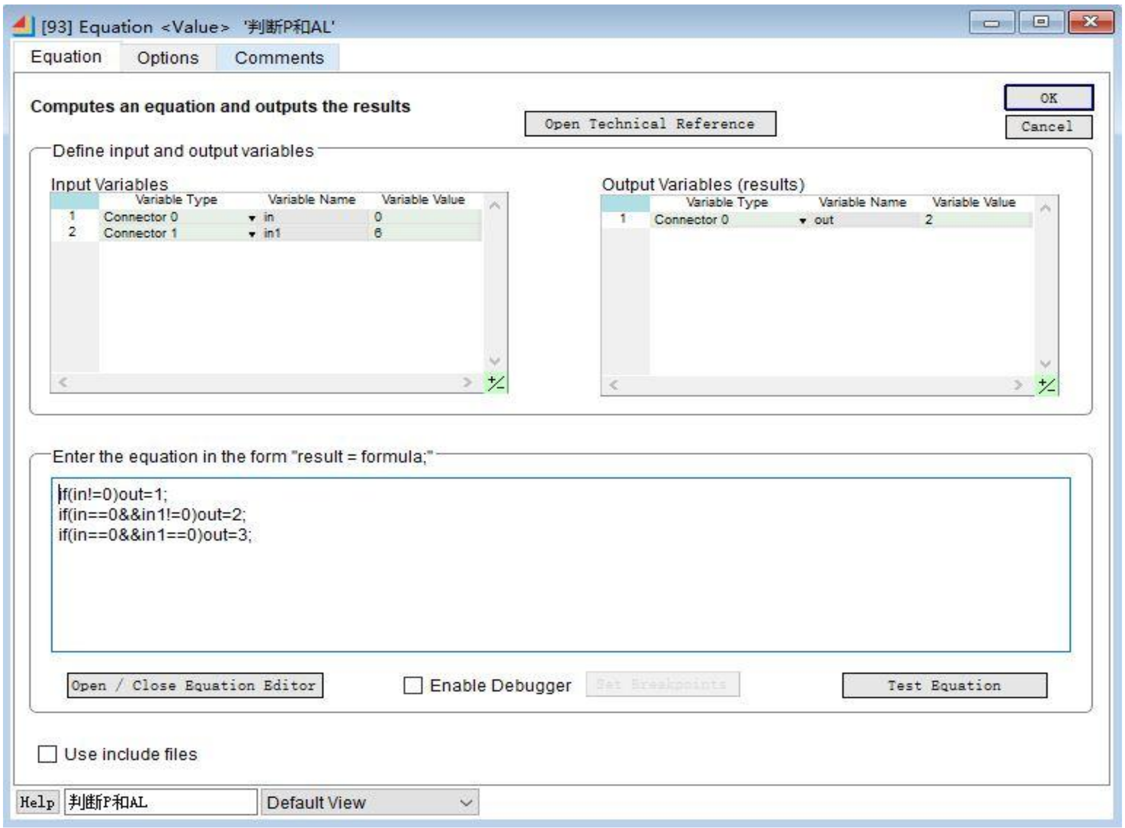


Figure 44: The specific code settings

Then, the patient is filed, which is divided into three steps: waiting for the corresponding resources, the filing process, and the resource release (taking AC resources as an example)

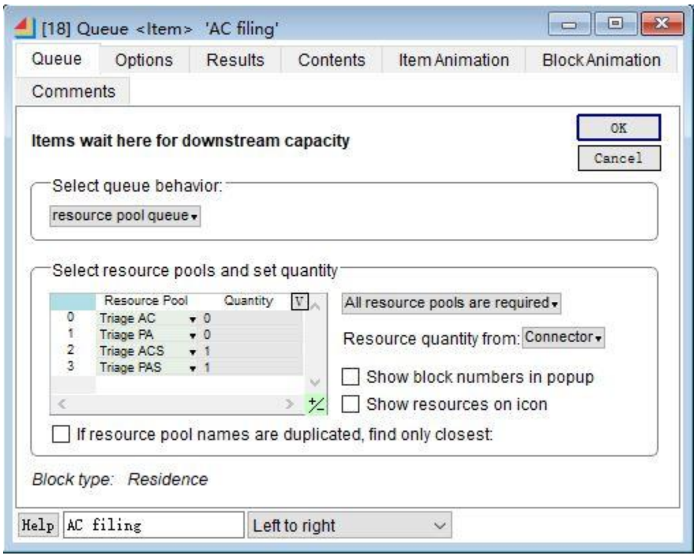


Figure 45: Resource waiting process

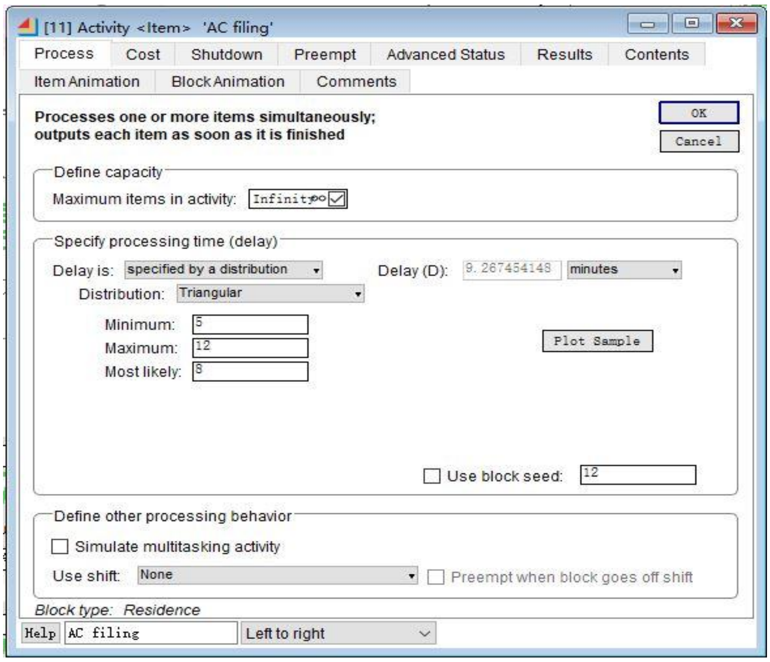


Figure 46: The documentation process

(2) Triage area

A schematic diagram of the entire module of the triage area is shown in Figure 47

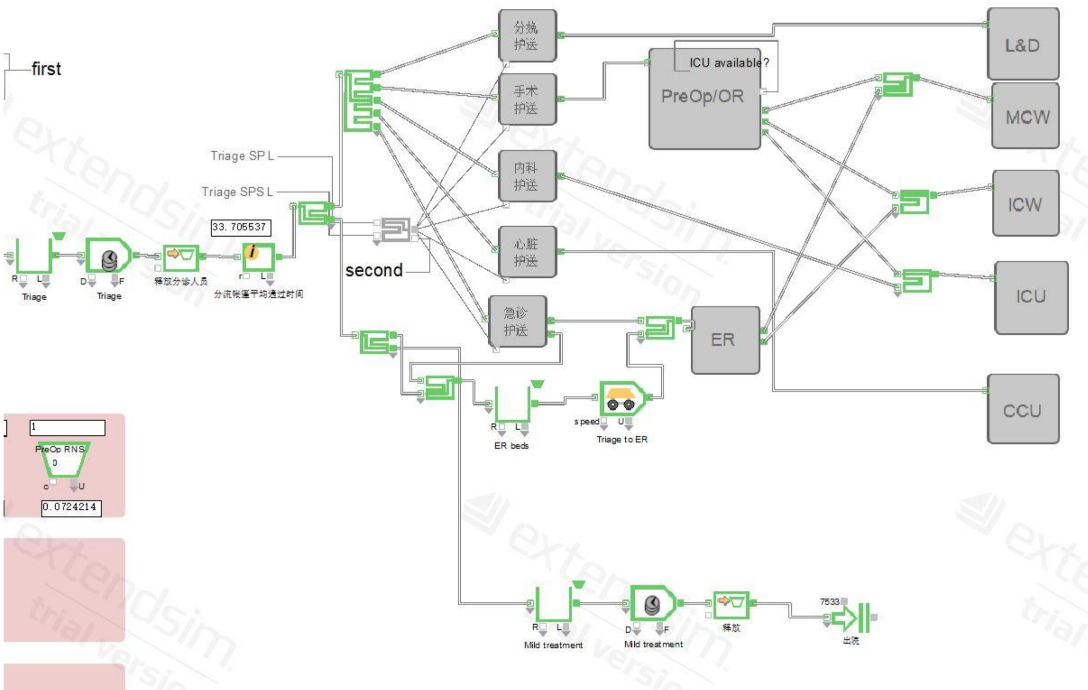


Figure 47: The entire module of the triage area

The triage of patients is divided into three steps: resource waiting, filing process, and resource release

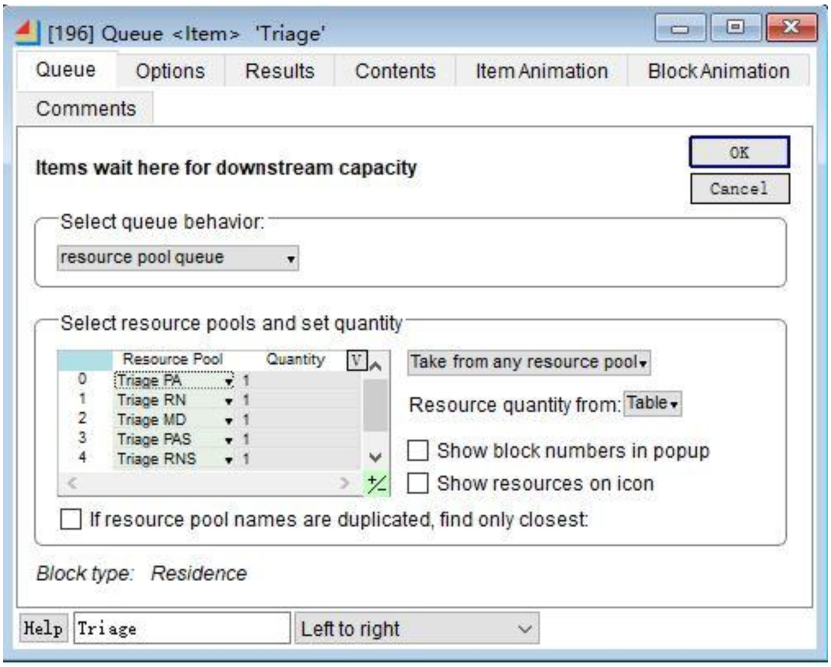


Figure 48: Triage resource waiting

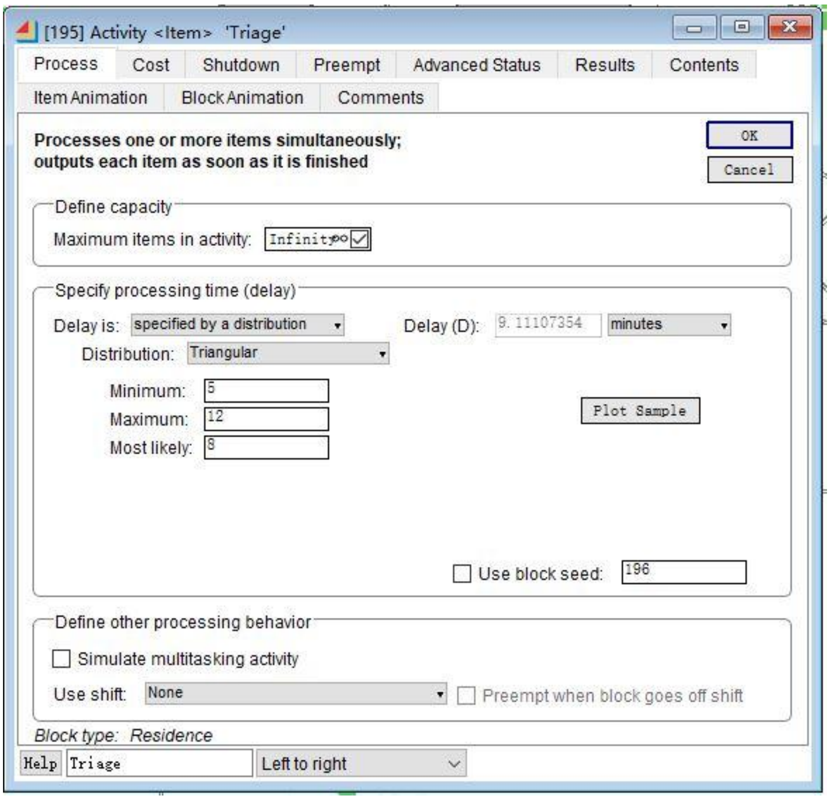


Figure 49: The documentation process

Triage identified severe (0.1) and moderate (0.9) injuries in patients with the following probability distributions:

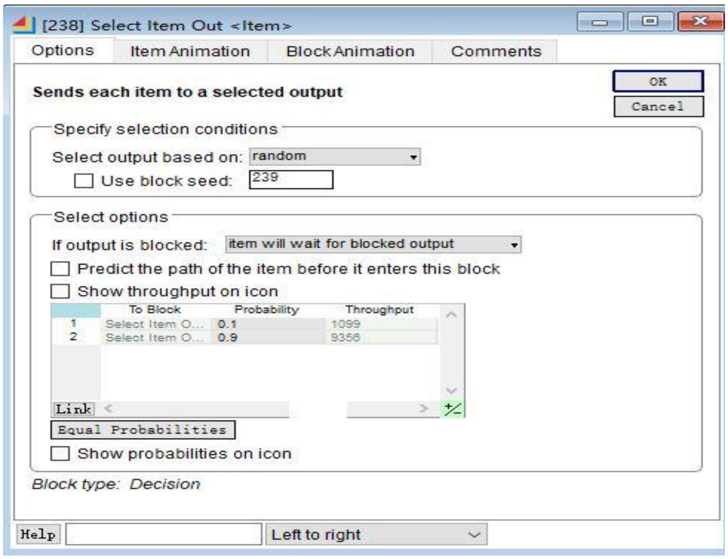


Figure 50: Patient injury probability distribution

Depending on the severity of the injury, personnel are escorted

Severe injuries were divided into 5 escort destinations: delivery area (0.03), operating room (0.38), ICU (0.25), CCU (0.06), ER (0.28) Moderate injuries were accompanied by only one escort destination: ER (0.19), and other patients were treated in the acute and mild diagnosis area in the triage tent and discharged on their own (0.81). The escort process takes escort to the delivery area as an example, and the process is as follows: the equation is used to control select item out to determine the personnel required for escort, and the logic is that the SP is the main person and the RN is the replaceable person, as shown in Figure 51

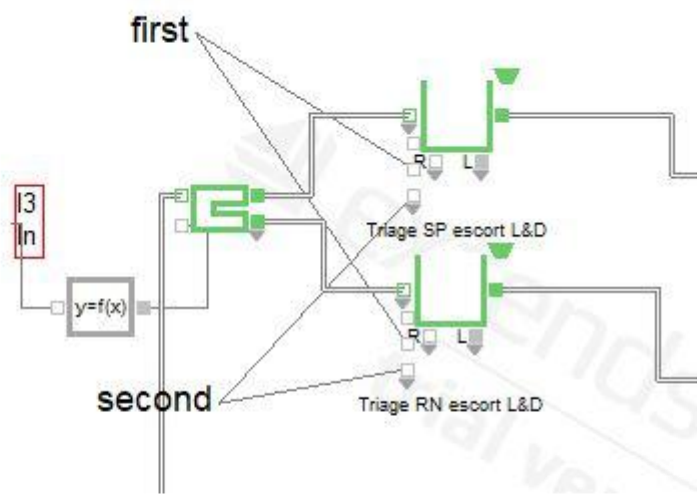


Figure 51: Personnel escorting

3.23 Anesthesia and operating rooms

(1) External structure

The anesthesia room and operating room modules have one physical inflow port, which flows in from the triage tent, and three physical outflow ports, which flow to the MCW, ICW, ICU

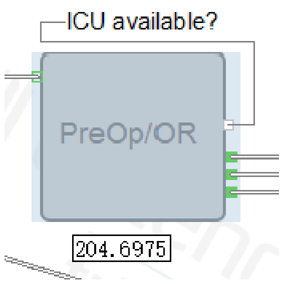


Figure 52: Schematic diagram of the external construction model

输入变量为 ICU beds 的可用数量用于判断 ICU 床位是否有剩余

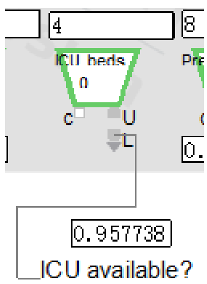


Figure 53: Judging the number of beds

(2) Preoperative preparation

The first thing a patient does when entering the anesthesia room is preoperative preparation

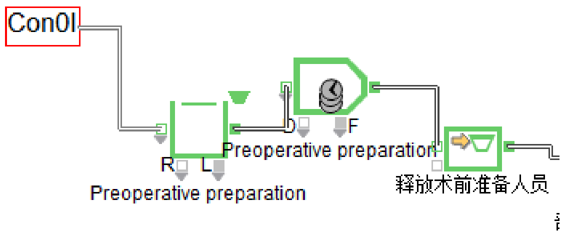


Figure 54: Preoperative preparation module

在资源模块需要用到 RN、MD、RNS、MDS

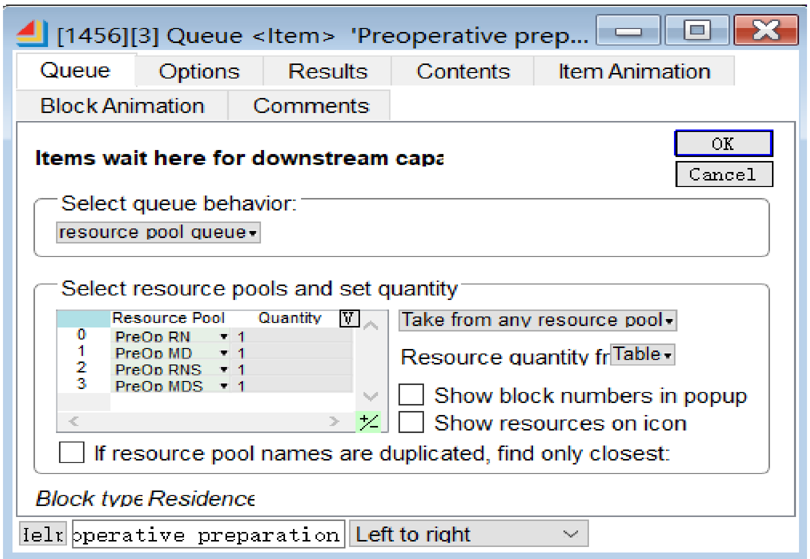


Figure 55: Resource acquisition

Then, fill in the specific distribution according to the time required for the activity of the data dictionary, and the minimum, maximum, and mode are 12, 24, and 17, respectively

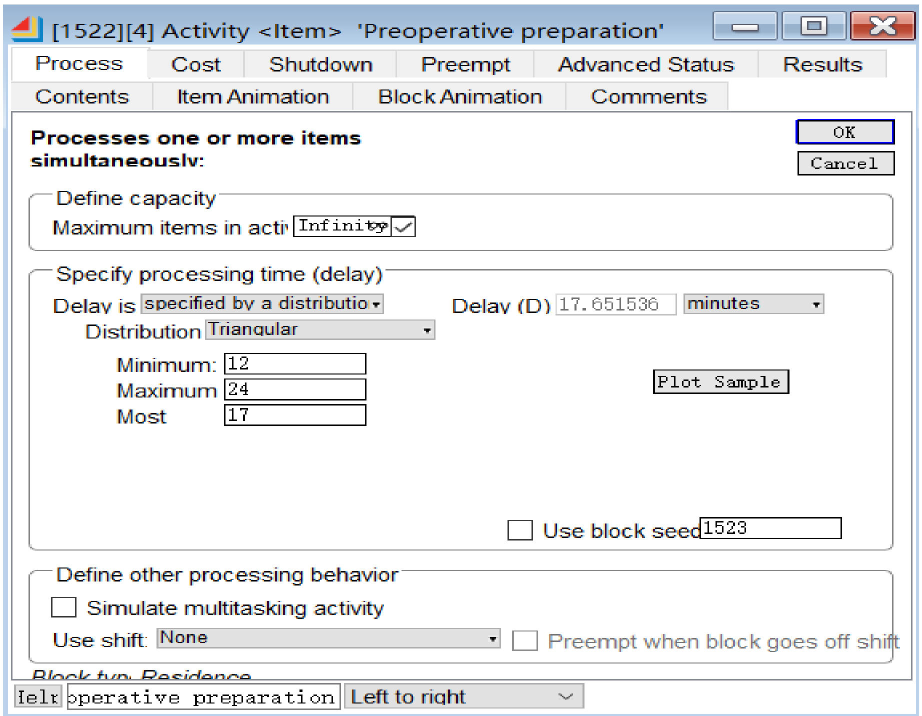


Figure 56: Activity time for preoperative preparation

Finally, the resources are released according to the attributes

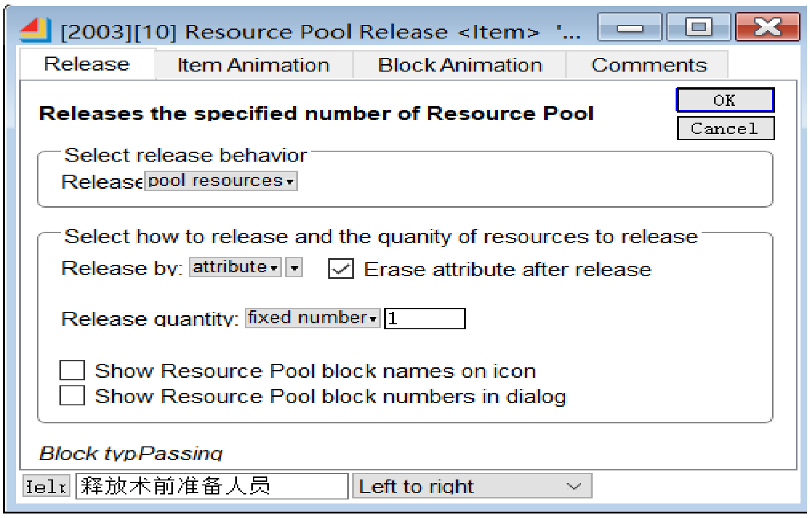


Figure 57: Release of preoperative preparers

(3) Laboratory examination and X-ray examination

After the preoperative examination, all patients required laboratory tests to facilitate subsequent surgery, but only 20% of patients required X-rays, which were triaged probabilistically using the Select Item Out module. If the patient needs to have an X-ray, the X-ray and the lab test can be done at the same time, and the staff will send the sample to the laboratory and wait in the queue for the laboratory personnel. At the same time, the patient enters the queue and waits for the staff to escort to the X-ray room for examination, and after being escorted to the X-ray room, he waits for XT to help him do the X-ray, and after the X-ray, he needs to wait for the laboratory staff to send back the test results before the follow-up operation can be carried out through the batch module. Laboratory tests are shown in Figure 58 and X-rays are shown in Figure 59

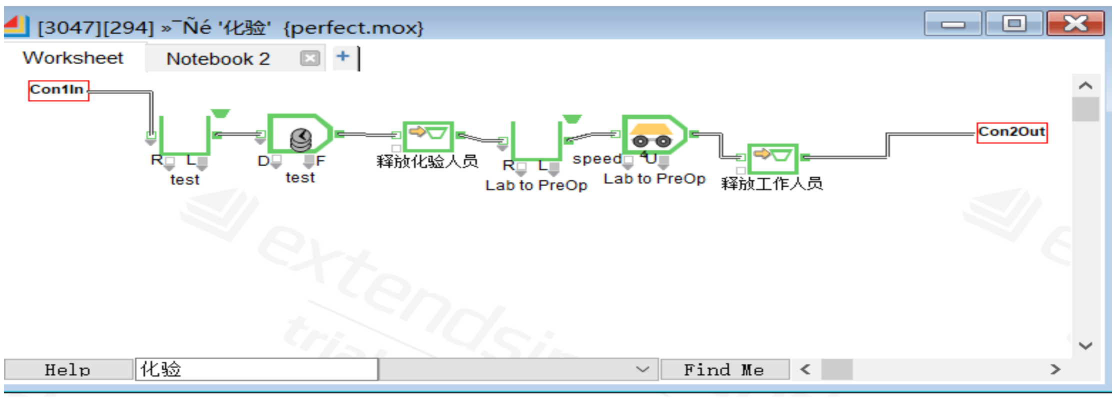


Figure 58 Laboratory examination

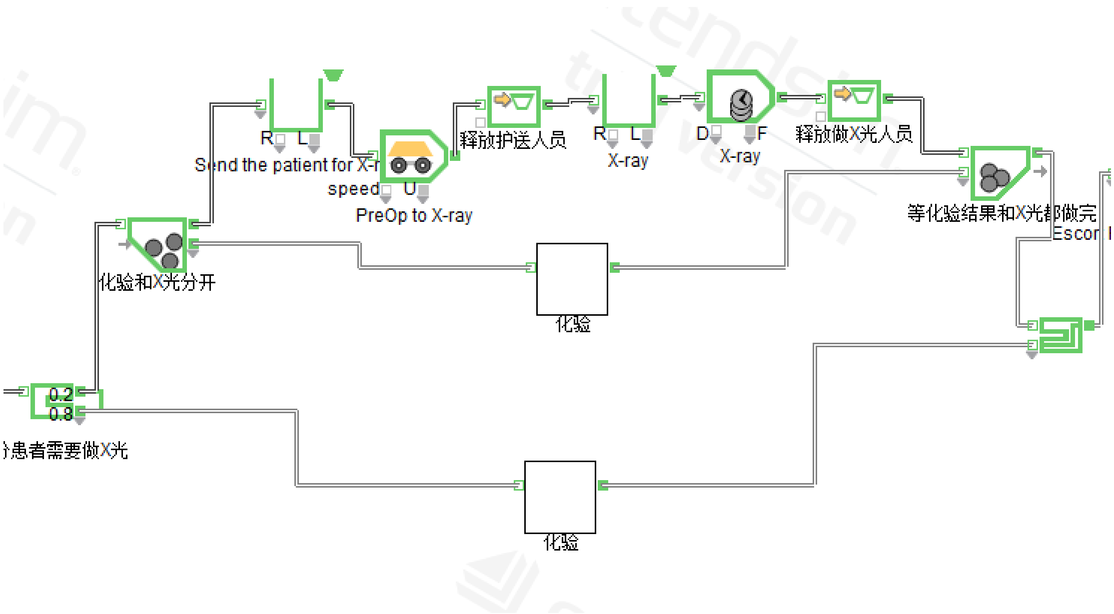


Figure 59: X-ray

The uniqueness of the batch and unbatch preservation of the entity allows each patient to be assured that they will receive their own test results. The specific settings are shown in Figure 60 and 61

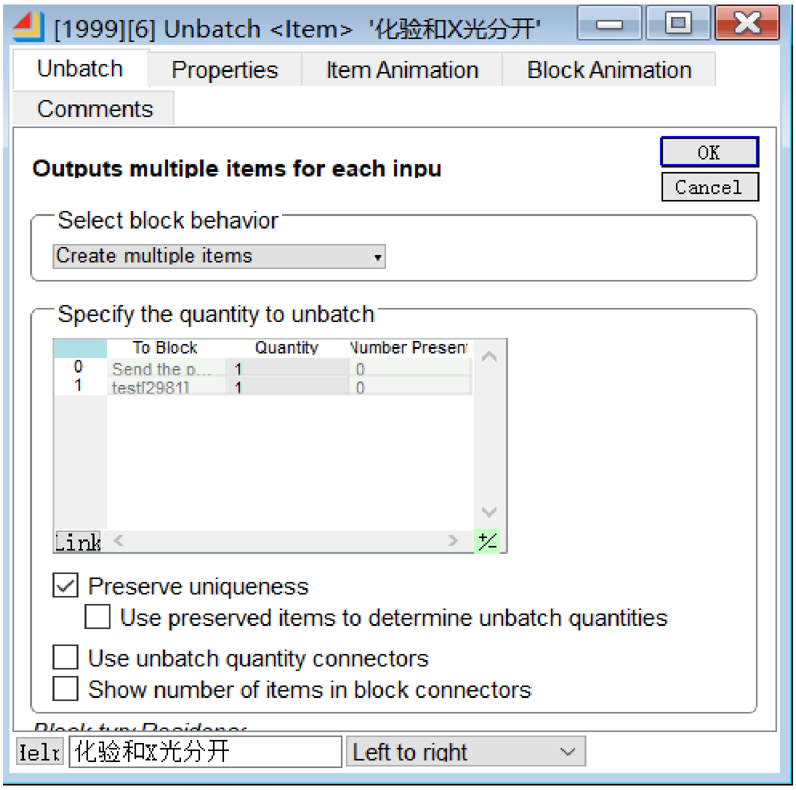


Figure 60: Separate lab and X-ray

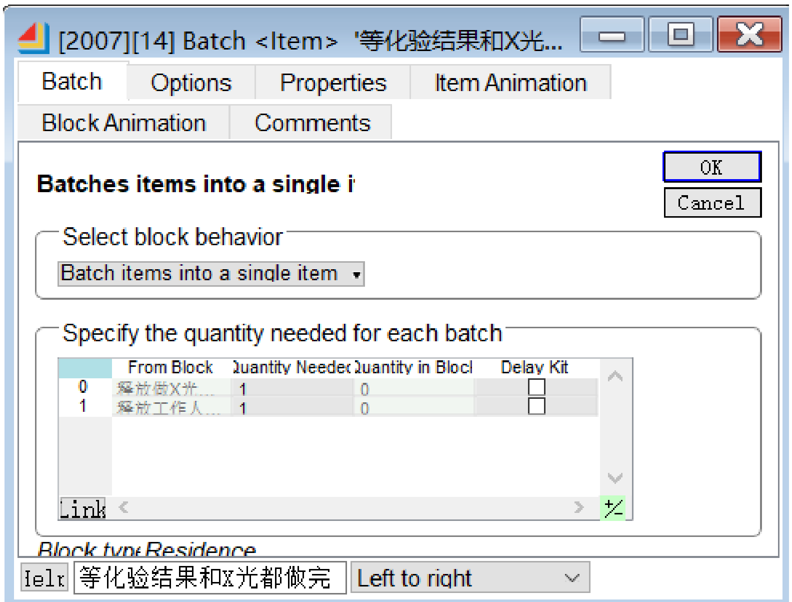


Figure 61: Isolab results with X-ray

This is followed by some specific parameter settings in this module

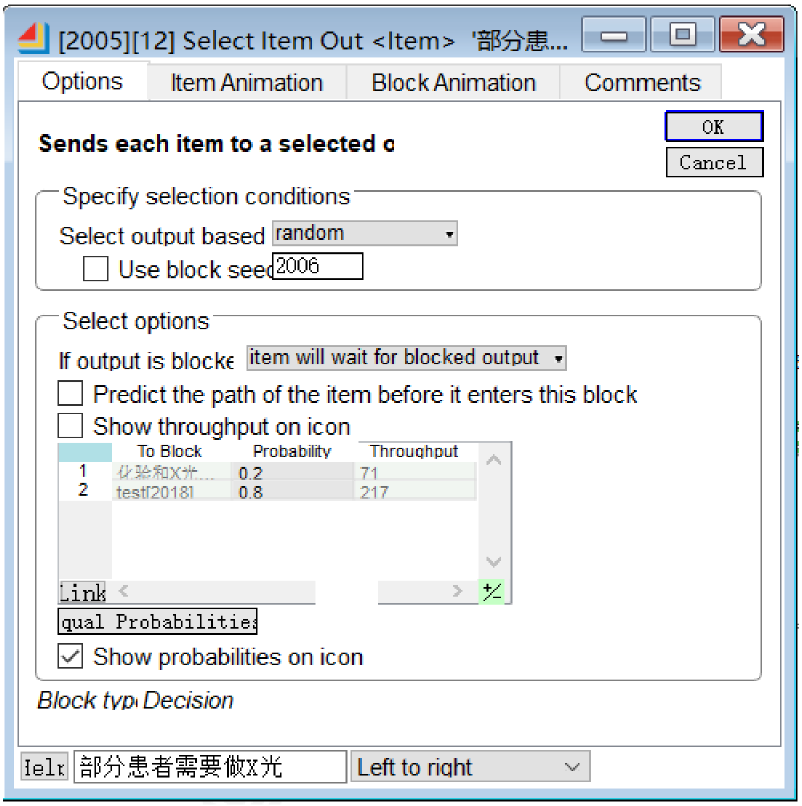


Figure 63: Shunt assays with X-rays of 0.2, other 0.8

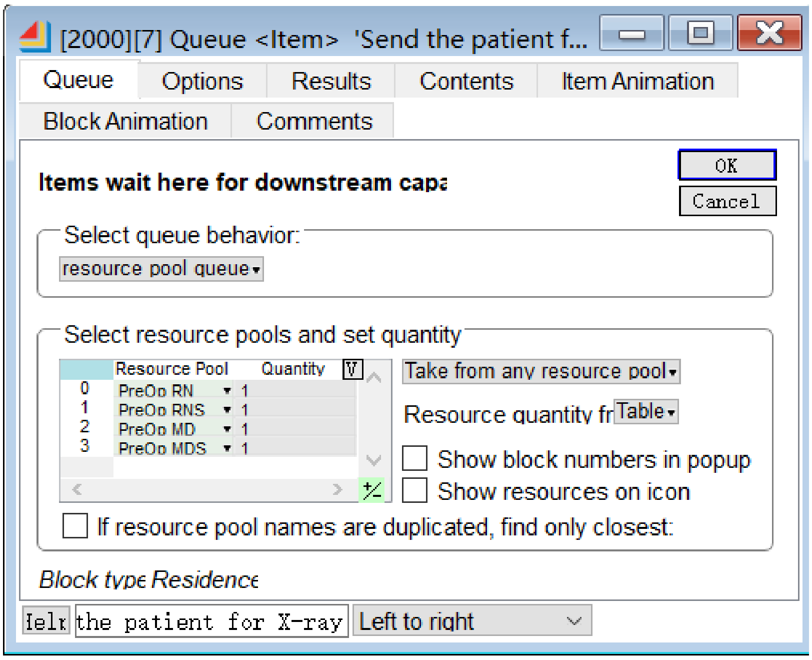


Figure 63: Resources required for laboratory tests and X-rays

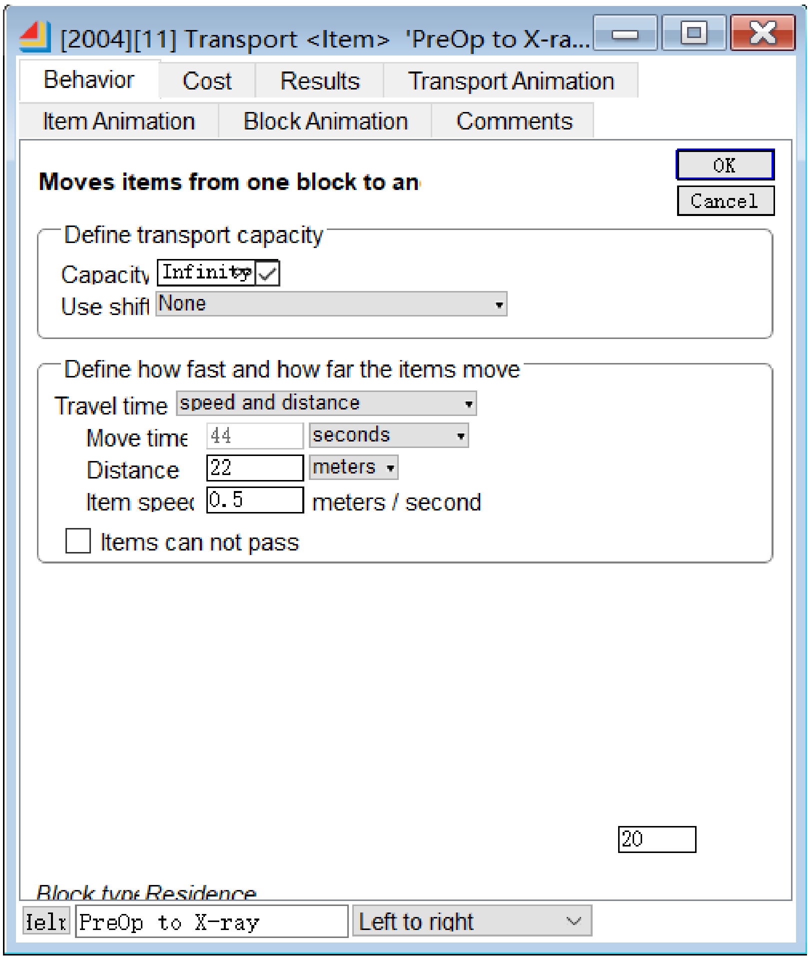


Figure 64: Patient movement setup for laboratory tests and X-rays

(4) The patient is transferred to the operating room, and the bed in the anesthesia room is reserved

A schematic diagram of the model of the bed reservation module is shown in Figure 65:

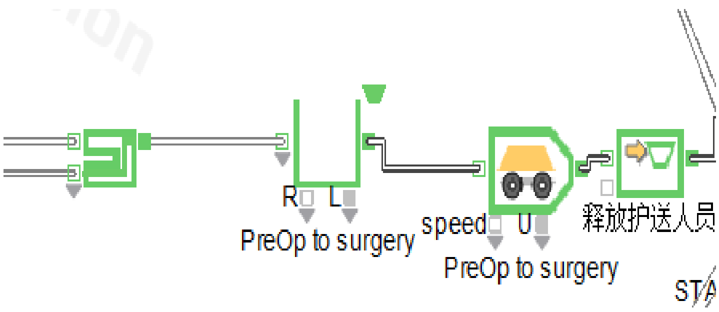


Figure 65: Bed reservation module

Patients who need to have X-rays and those who do not need to have X-rays are pooled into the queue through the Merge option in Select Item In and wait for the staff to escort them to the operating room, and the bed resources are not released, i.e., the bed is reserved. The specific settings are as follows:

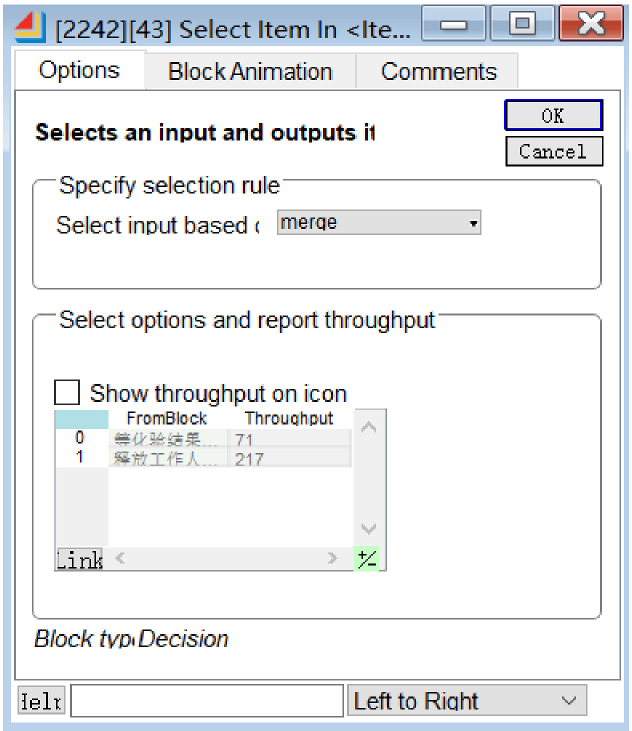


Figure 66: Merge shunt

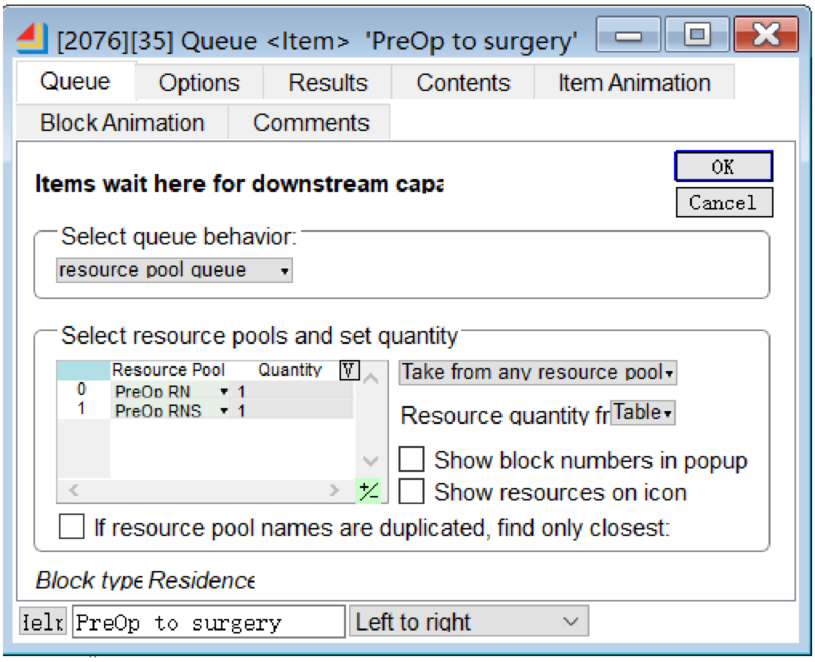


Figure 67: Resource requirements for retention

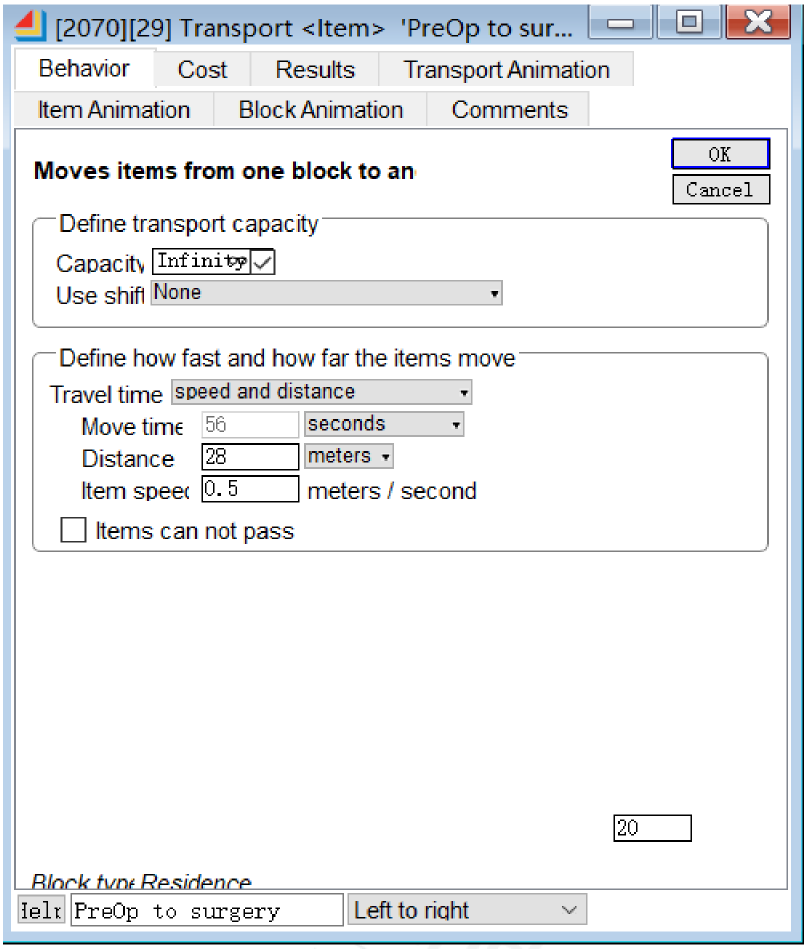


Figure 68: Settings for the speed of movement of the escort personnel

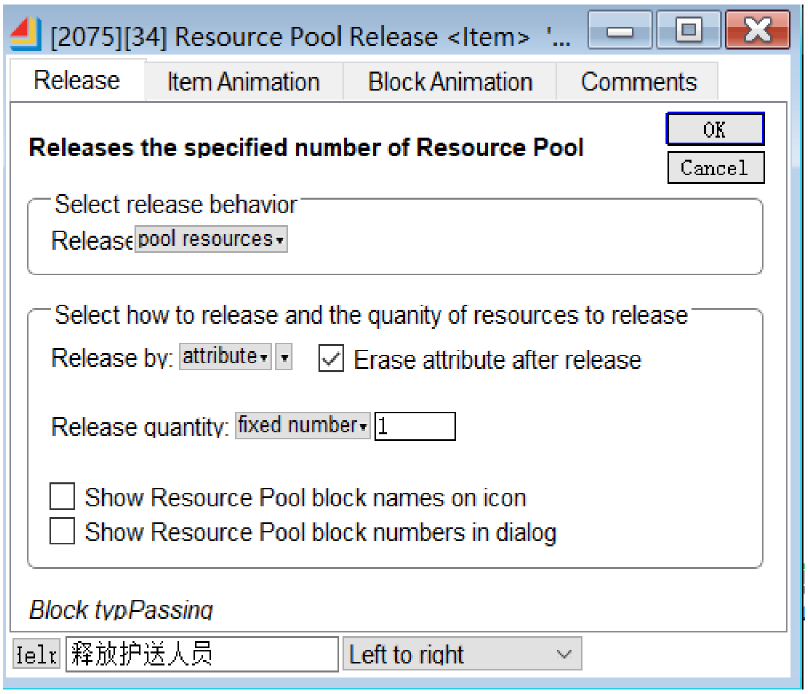


Figure 69: Escort release

(5) Surgery and post-operative recovery

A schematic diagram of the model of the module is shown in Figure 70:

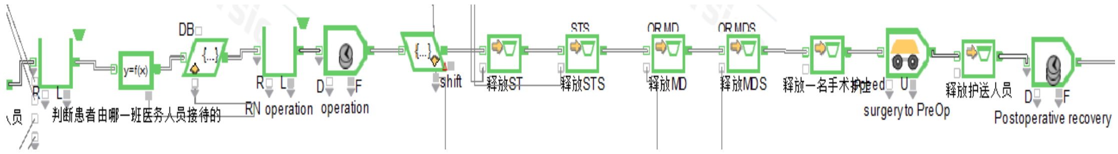


Figure 70: Surgery and postoperative recovery module

After the patient is transferred to the operating room, he needs to wait for one MD and one ST and two RNs to be available at the same time before the operation can be performed, and after the operation, both ST and MD are released, one RN is released, and the other escort the patient back to the operating room is released after rest

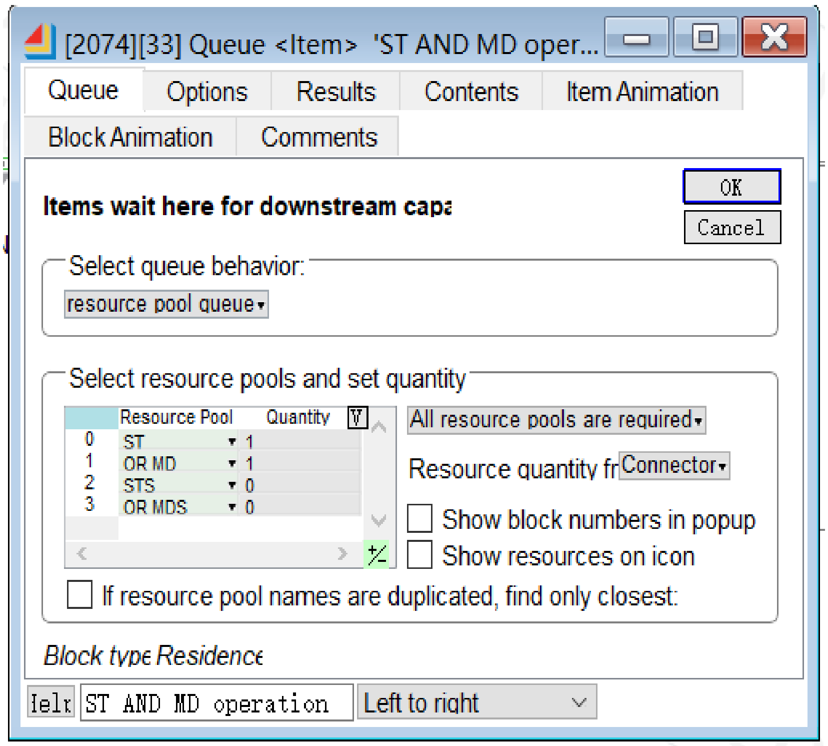


Figure 71: Resources required for transfer to the operating room

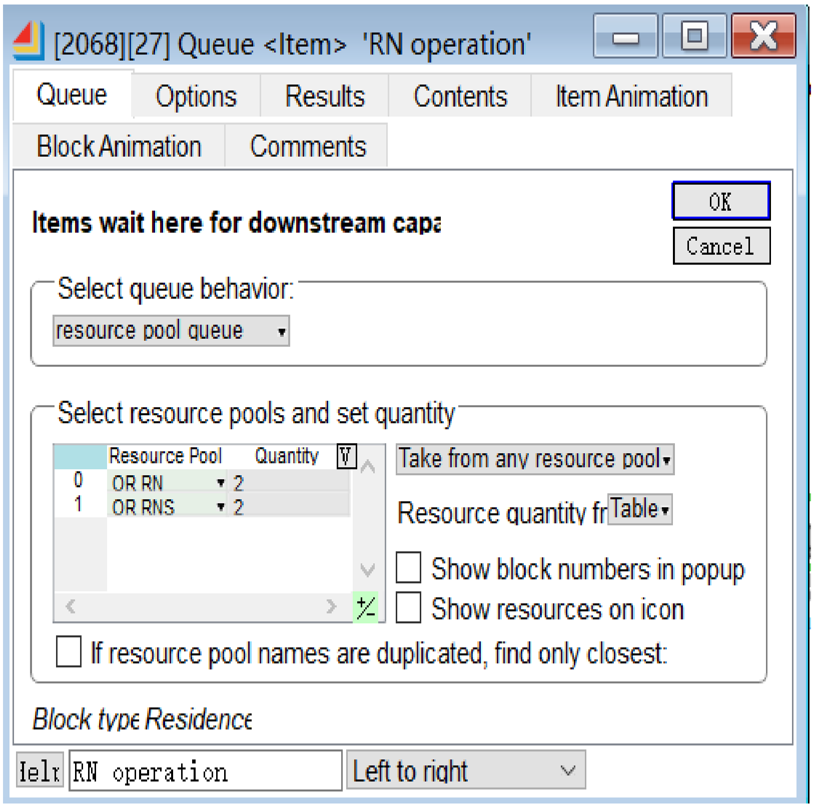


Figure 72: Resources required for surgery

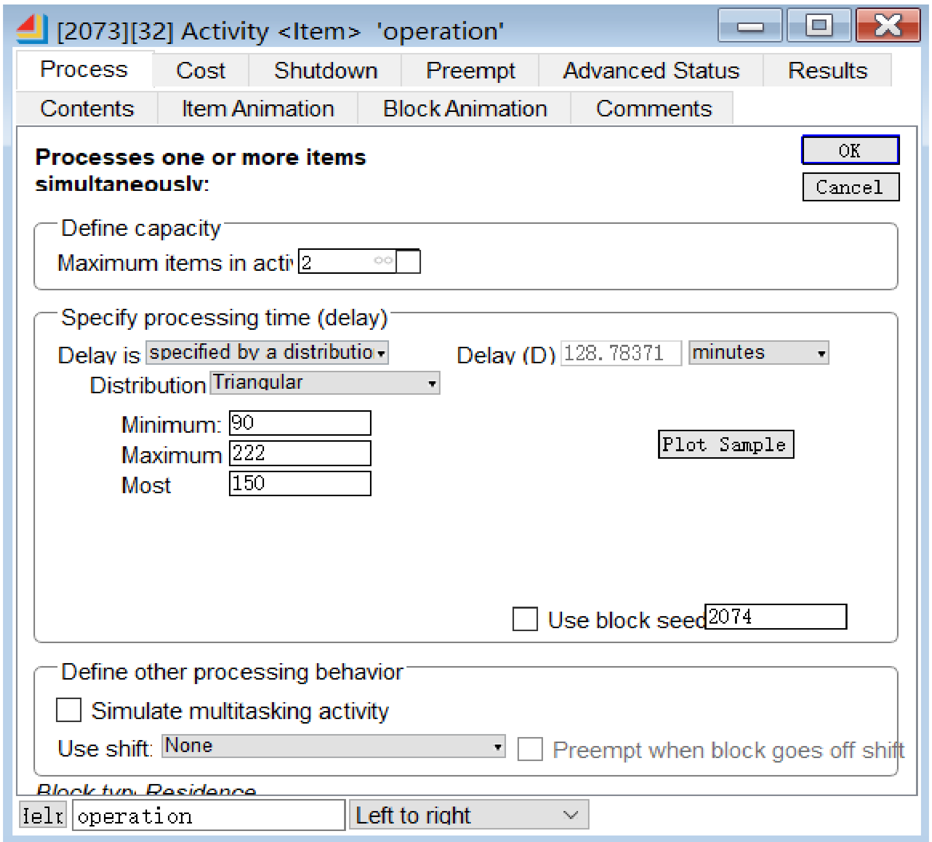


Figure 73: Operative time of the operation

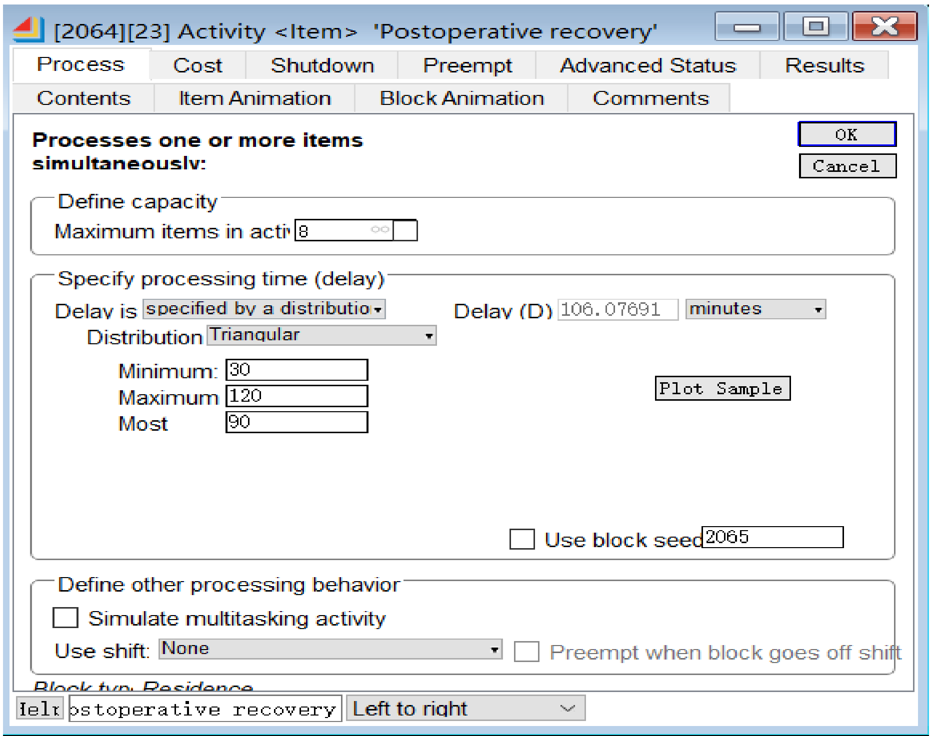


Figure 74: Time to recovery of the patient

（6）患者转入 ICW、ICU、MCW

A schematic diagram of the overall module model is shown in Figure 75:

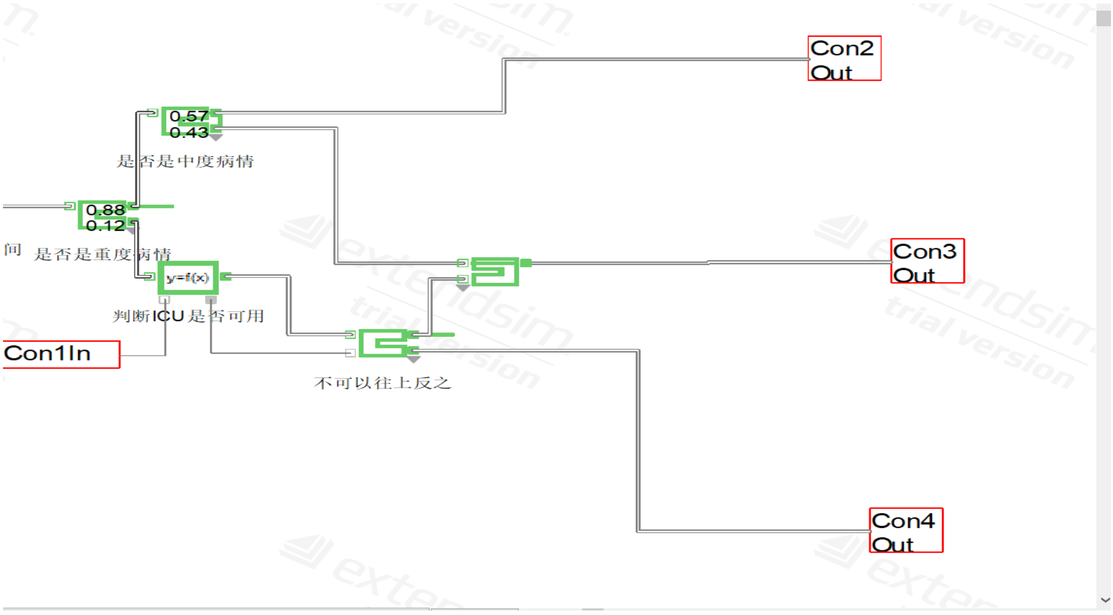


图 75：患者转入 ICW、ICU、MCW

A schematic diagram of the specific model transferred to each ward is shown below

Figure 76: Transfer to MCW

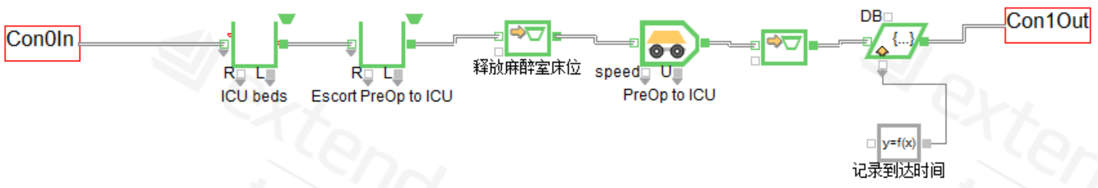


Figure 77: Transfer to ICW

Figure 78: Transfer to ICU

The logic of the model is as follows: the patient needs to be transferred after postoperative recovery, first determine whether the patient is severely ill, then determine whether the patient is moderately ill, if not, it is mild, the patient is transferred to MCW, if it is moderately ill, then to ICW, if it is seriously injured, first determine whether there is an empty bed in the ICU, if there is a transfer to the ICU, otherwise the patient will be arranged to ICW. The beds they occupy will not be released until the patient is transferred. The code for the specific settings is shown in Figure 79

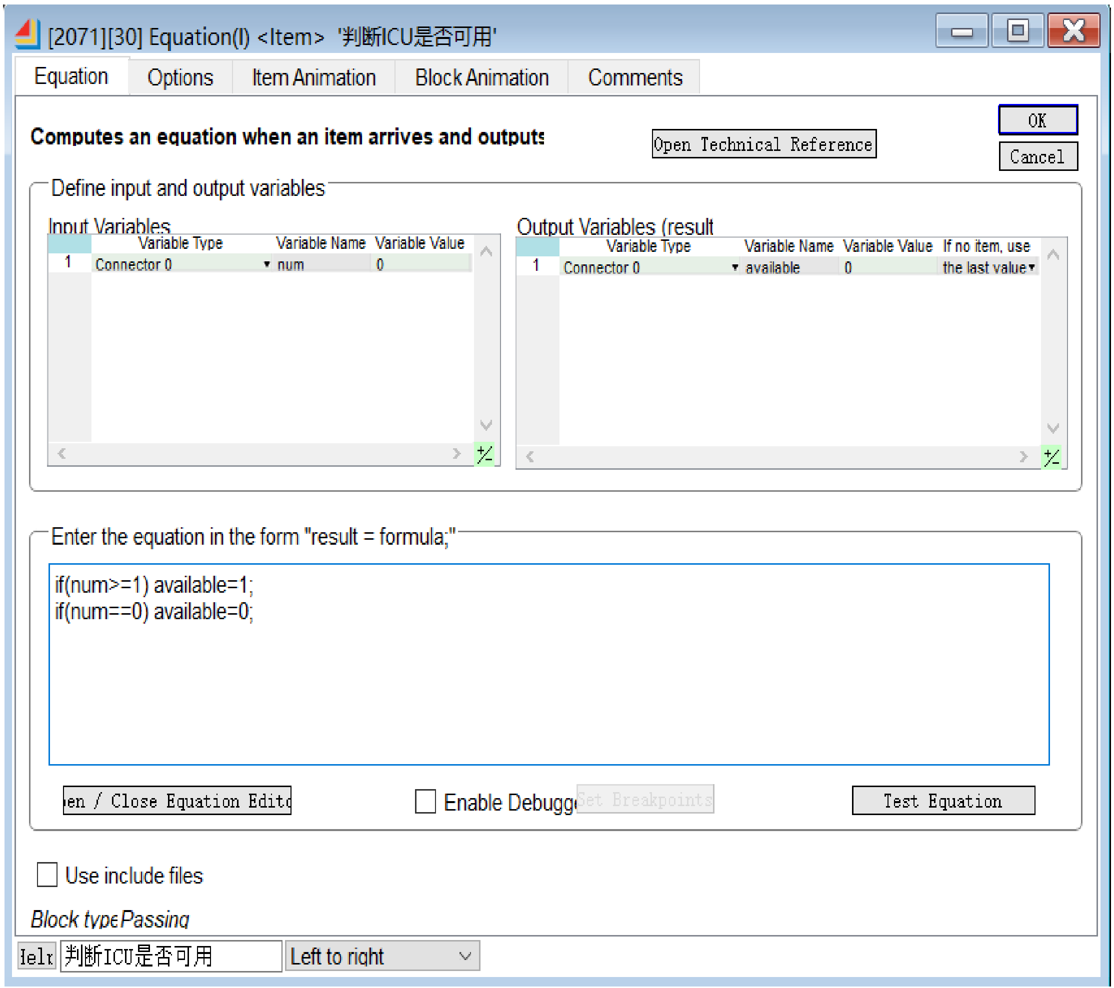


Figure 79: Determining whether the ICU is available

3.24 Birthing area

(1) The design logic and model diagram of the delivery area

The patient enters from the interface and uses Unbatch to divide the entity into two and perform both labor and lab tests at the same time, as the patient can be done without being on-site during the test. Because there is no assay to take the risk of survival, entities will not merge until both activities have been completed, and activities that have been completed earlier will not be merged until another activity has been completed. Then you need to get the resources of doctors and nurses to carry out the delivery activities, the delivery activity time obeys the triangular distribution in the data dictionary, the doctors and nurses can be released after the delivery, the expression of childbirth is also the use of Unbatch, and the pregnant woman's recovery and the baby's stay can be completed at the same time before leaving together, check Preserve uniqueness in the Batch to ensure that the pregnant woman takes away her baby, and then leave the hospital and release the bed in the delivery area. The schematic diagram of the specific model is shown below

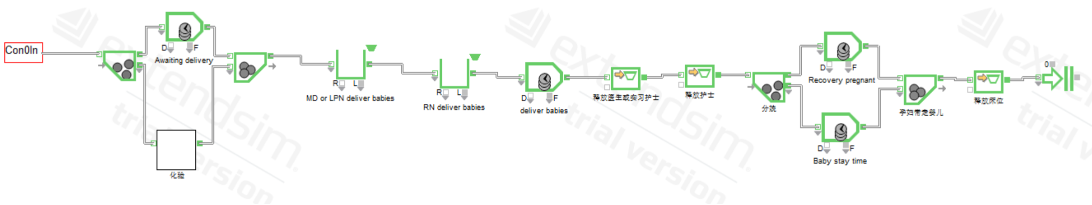


Figure 80: Birthing area module

(2) The design logic and model diagram of the laboratory area

When the patient arrives at the laboratory area, he is responsible for the laboratory according to whether there are LT resources now, and if there are no LT resources, the patient needs to wait, and the LT in the required resources is the first shift, and the LTS is the second shift, and the LTS resource requirement will be 0 when LT goes to work, and the same is true for the resource queue below. After the patient gets the LT resources, the laboratory activities are carried out, obeying the triangular distribution, and the laboratory personnel are released after the laboratory is completed, and then the laboratory report is sent to the delivery area by the staff, and then the staff is released to complete the follow-up activities from the Con2Out interface. The schematic diagram of the specific model is shown below

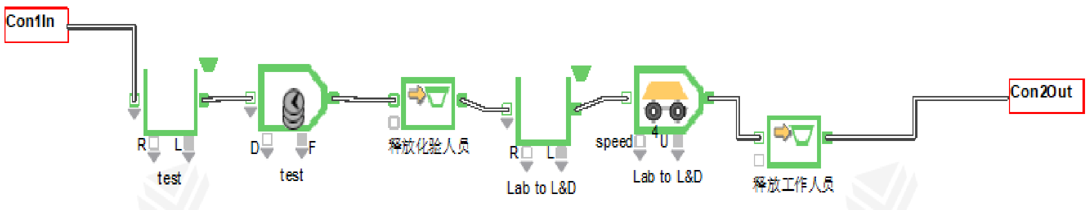


Figure 82: Assay area module

(3) The setting of some specific modules in the delivery area

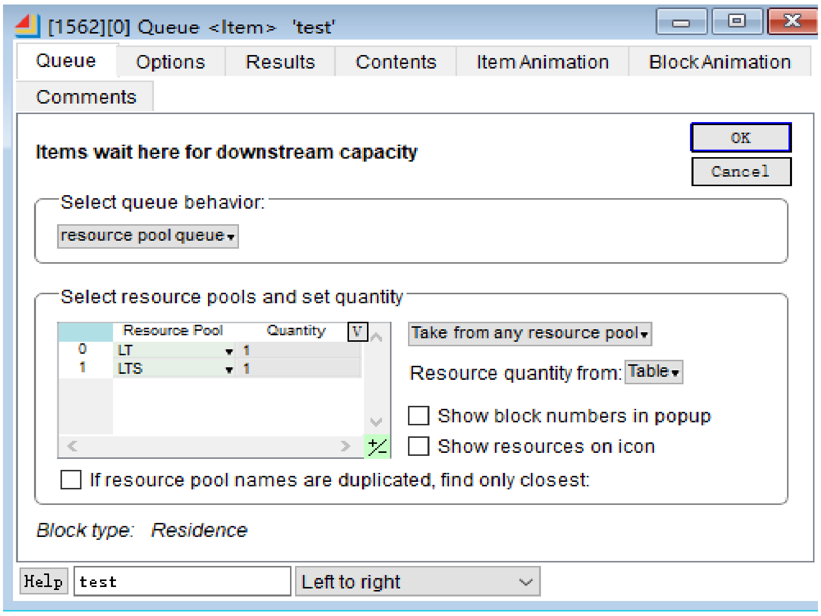


Figure 83: Resource requirements for assays

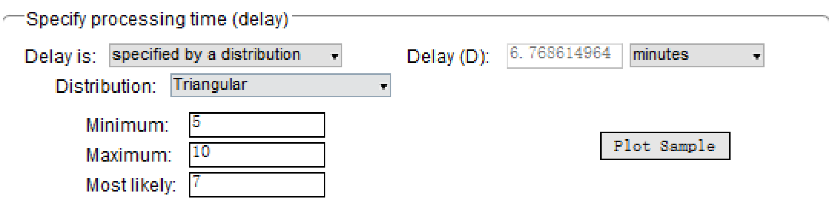


Figure 84: Assay time follows a triangular distribution

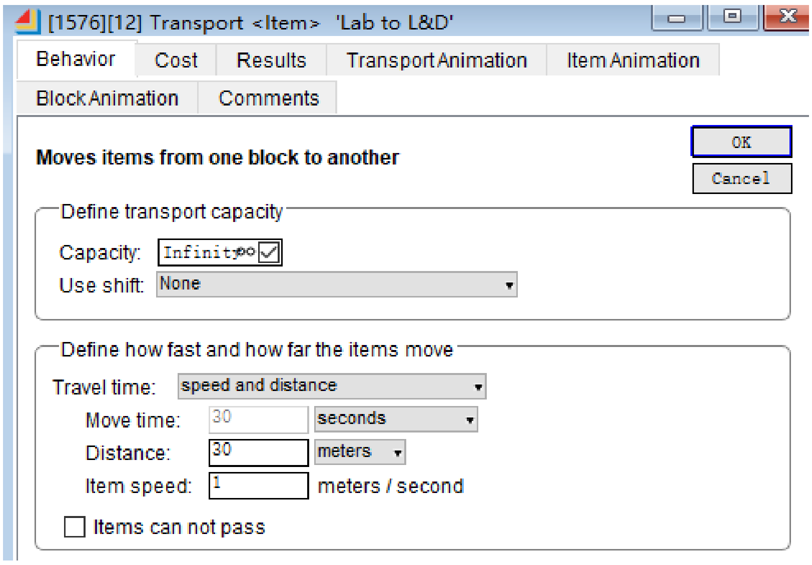


Figure 85: Design of the module for the distance in which the test results from the

assay area are sent to L&D

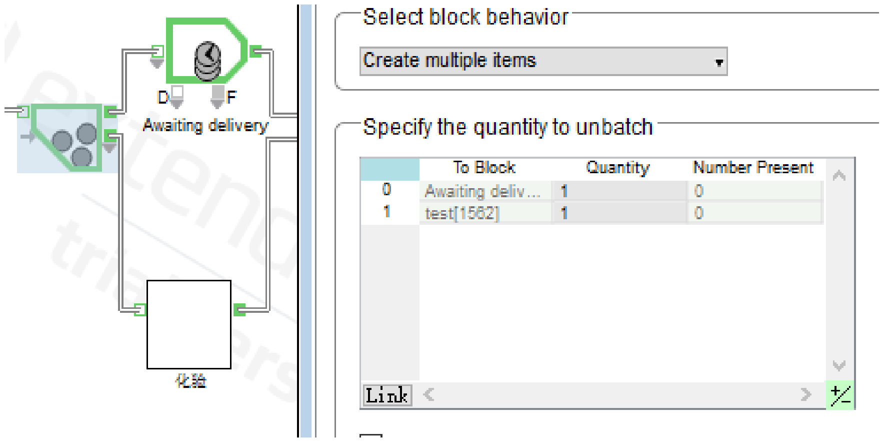


Figure 85: Assay unbatch module

When the delivery doctor or the doctor is not available, the name and quantity of the resource pool used are recorded as new attributes a and b, so that when the MD resources are insufficient, the LNP can be replaced in time and the corresponding number of resources can be released according to the corresponding resource pool.

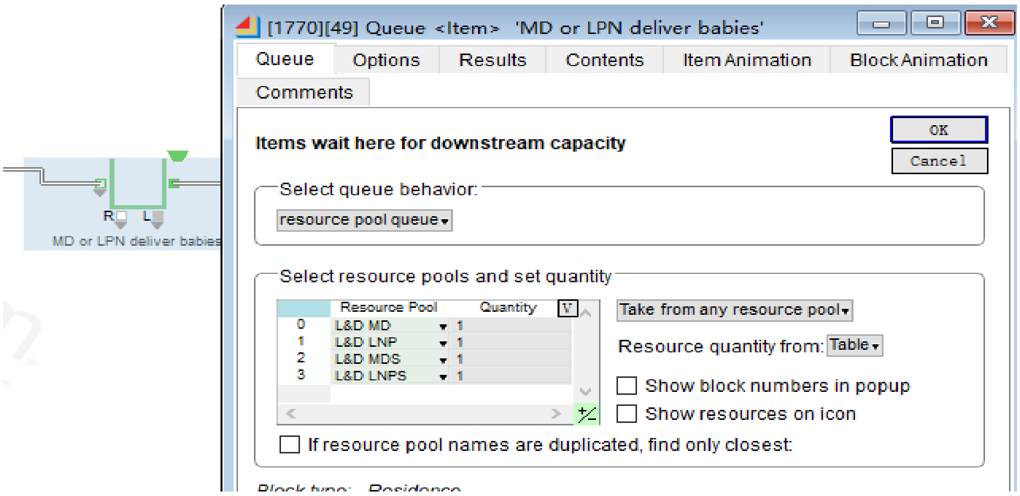


Figure 86: Resource requirements for childbirth

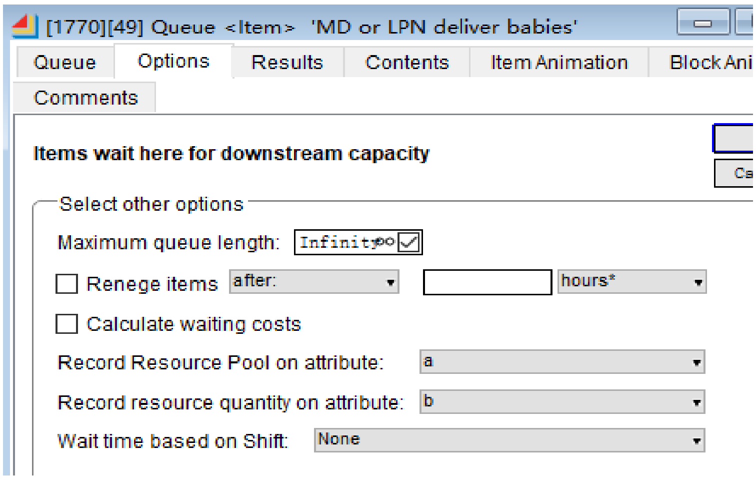


Figure 87: Transportation of neonatal resources

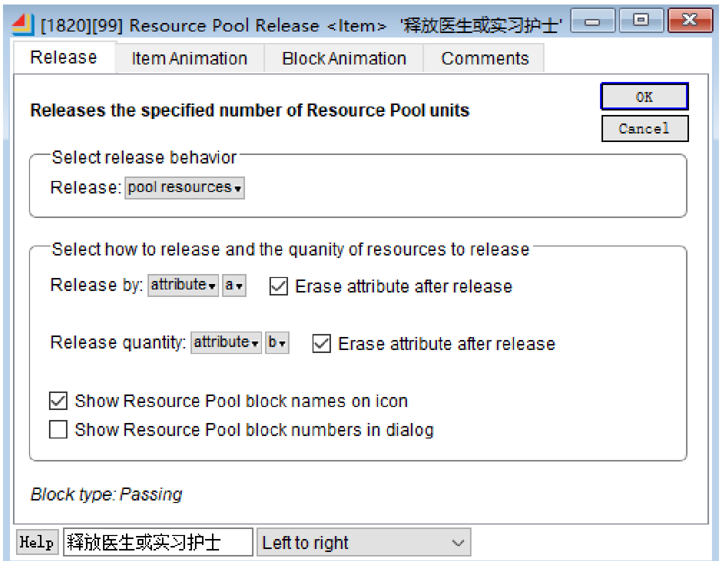


Figure 88: MD and alternate LNP resource release module settings

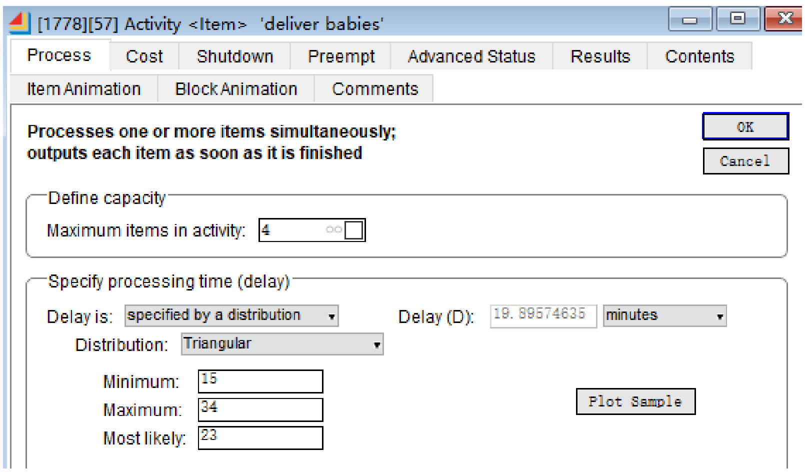


Figure 89: Delivery times follow a triangular distribution

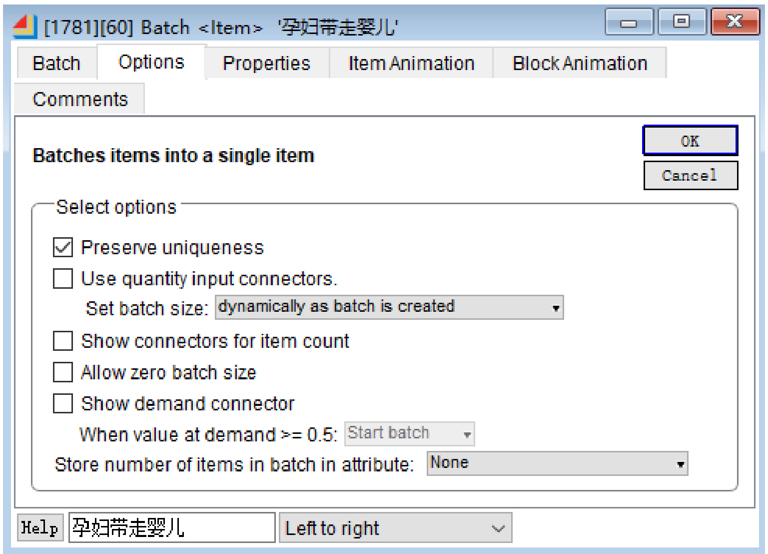


Figure 90: Pregnant woman taking her baby

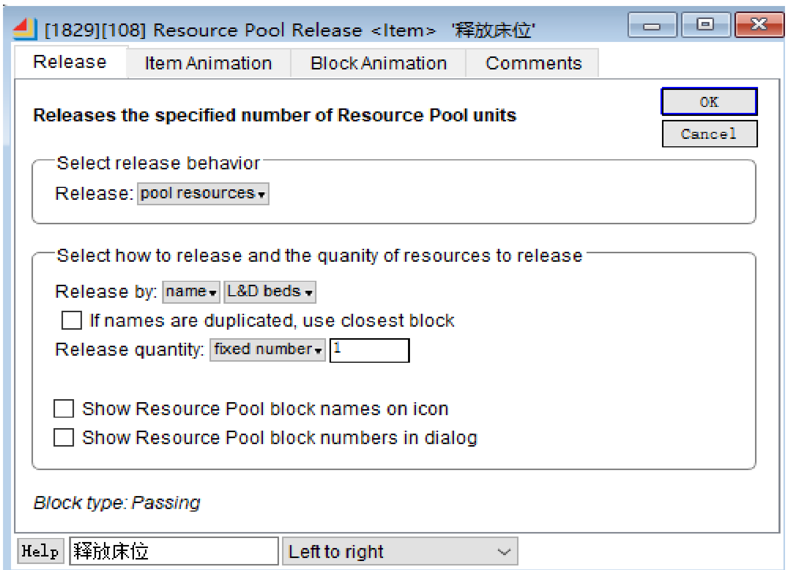


Figure 91: Beds in the delivery area are released after the woman leaves

3.25 Emergency area

The emergency department is divided into a diagnostic area and a treatment area; This is shown in the figure below

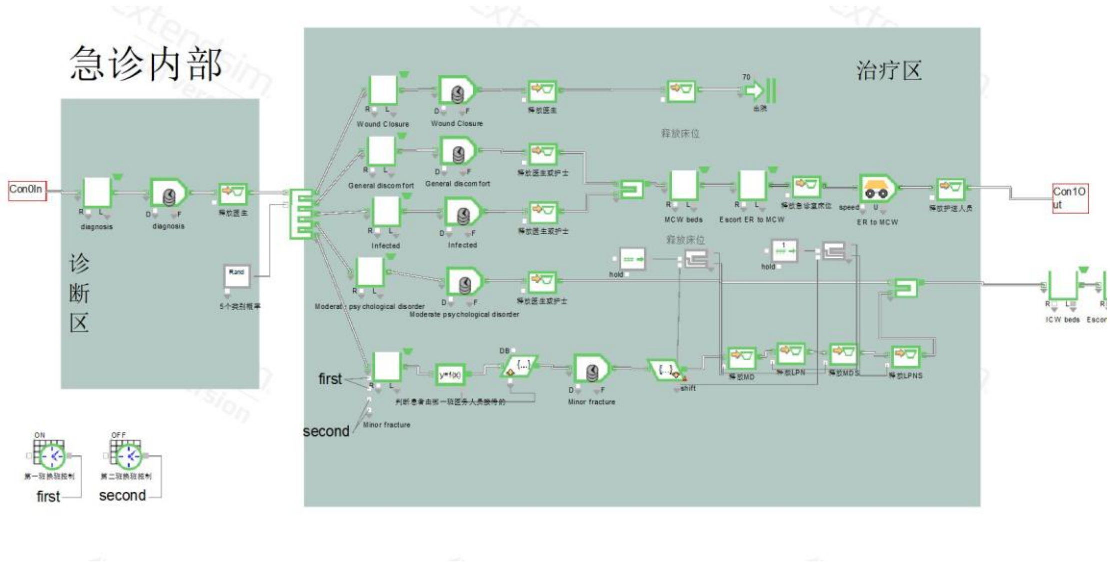


Figure 93: Schematic diagram of the emergency general module

(1) Diagnostic area

The resource needed is a doctor

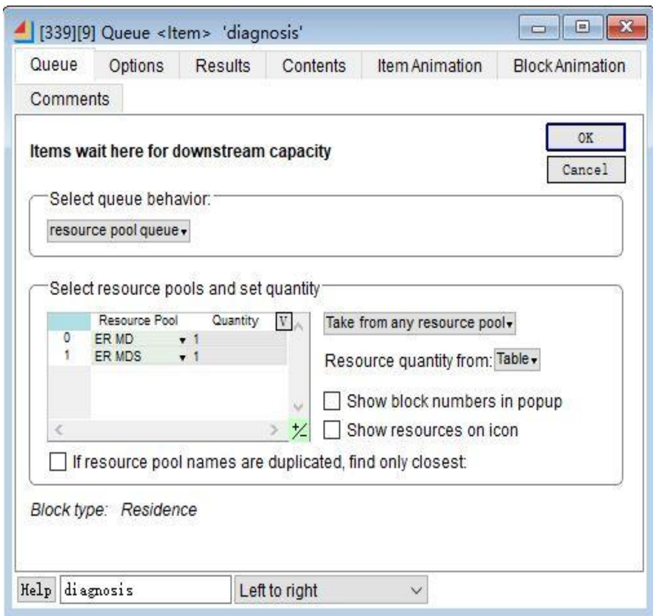


Figure 94: Physician resources required

Diagnostic process

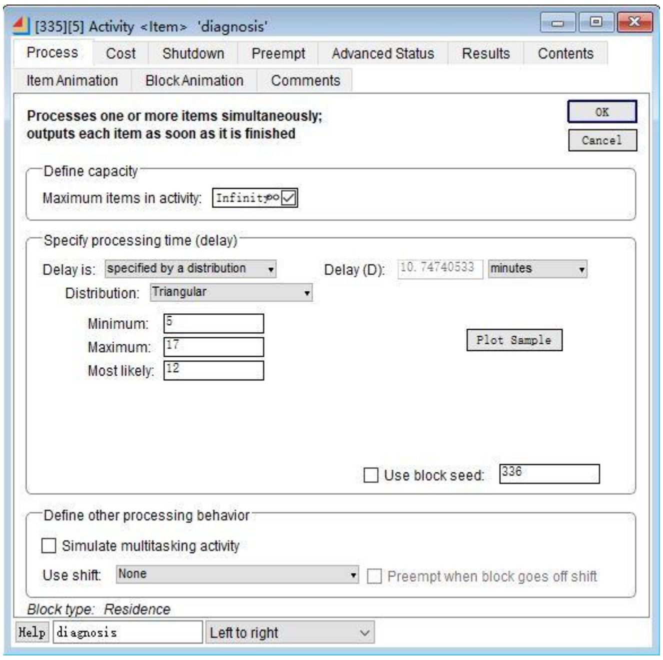


Figure 95: Diagnostic process

诊断资源释放，根据 resource pool queue 所定的资源属性，利用 Resource pool release 模块进行医生资源释放。

Figure 96: Releasing physician resources

Doctors triage 5 categories of conditions and triage them by selecting item out, with the following probabilities

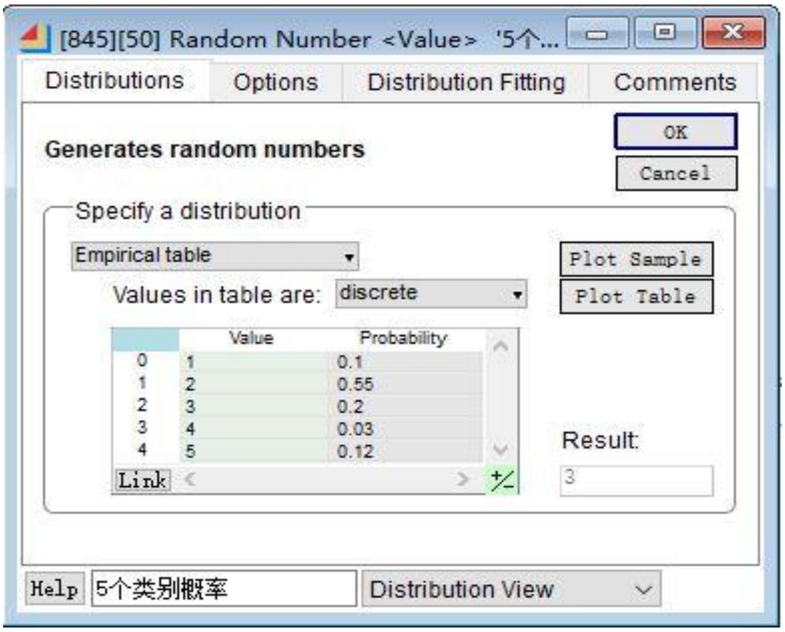


Figure 97: Shunt probability

(2) Treatment area

Taking wound suturing as an example, it is carried out in three steps: resource waiting, treatment process, and resource release (the other four treatments are similar)

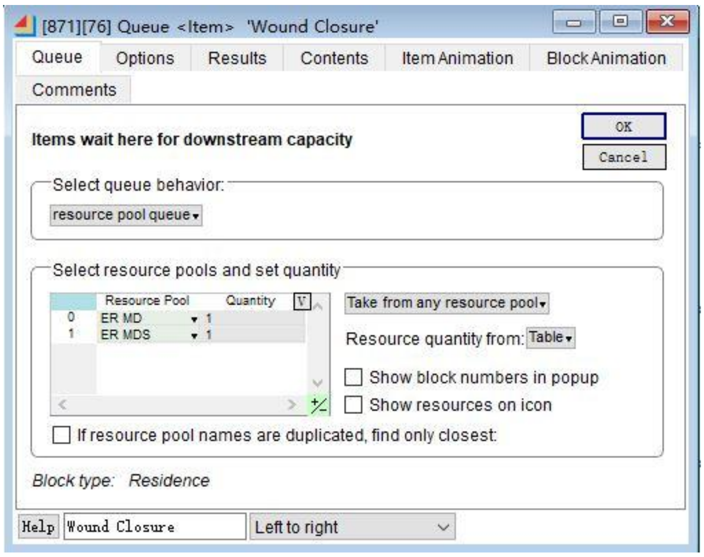


Figure 98: Resource requirements for treatment areas

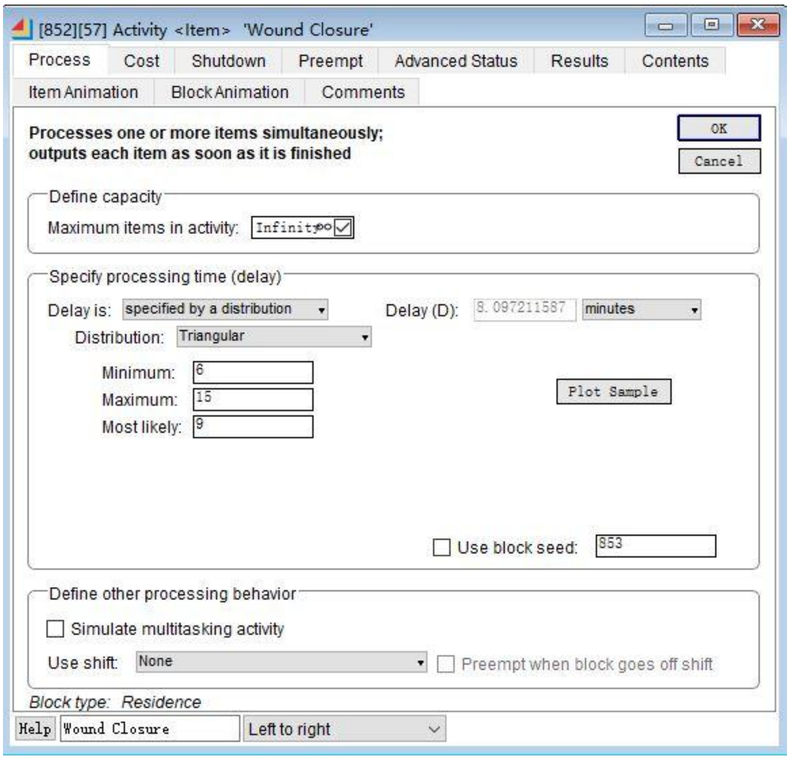


Figure 99: Treatment area activity time

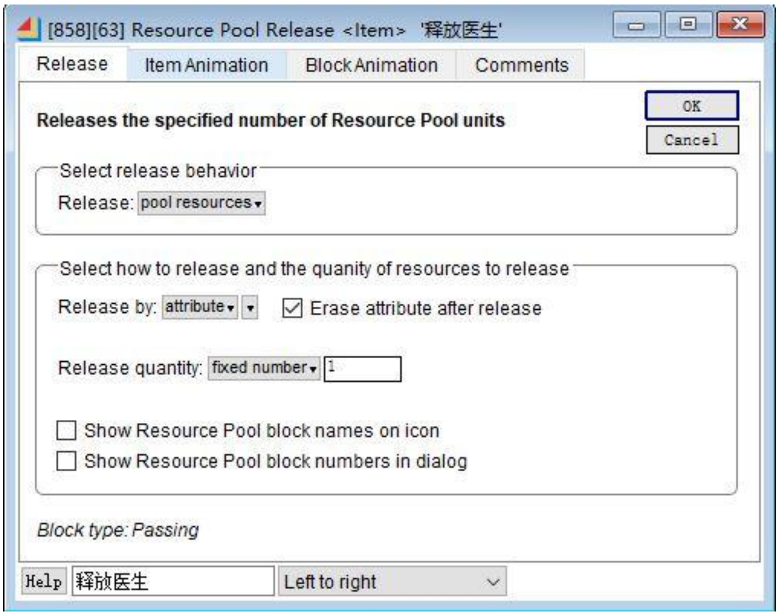


Figure 100: Unlocking physician resources

3.26 Mild, moderate, and severe wards and cardiology wards

(1) Construction of the overall model of the ward

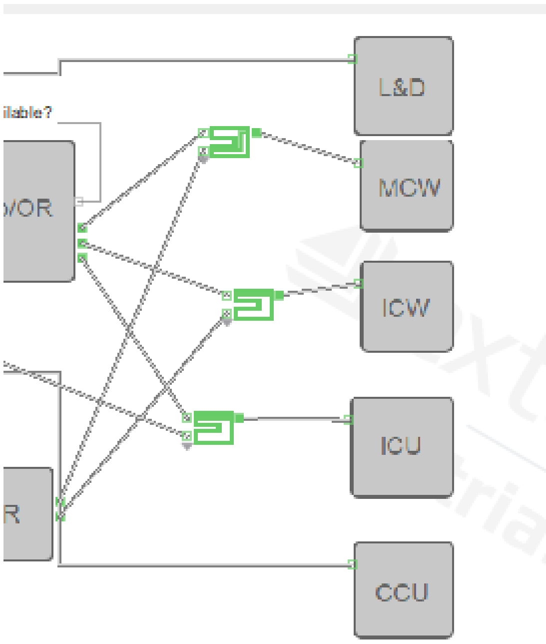


Figure 101: Overall model construction for each ward

Because the process and details of each ward are similar, only one model module of the ward is used for interpretation and presentation for each module

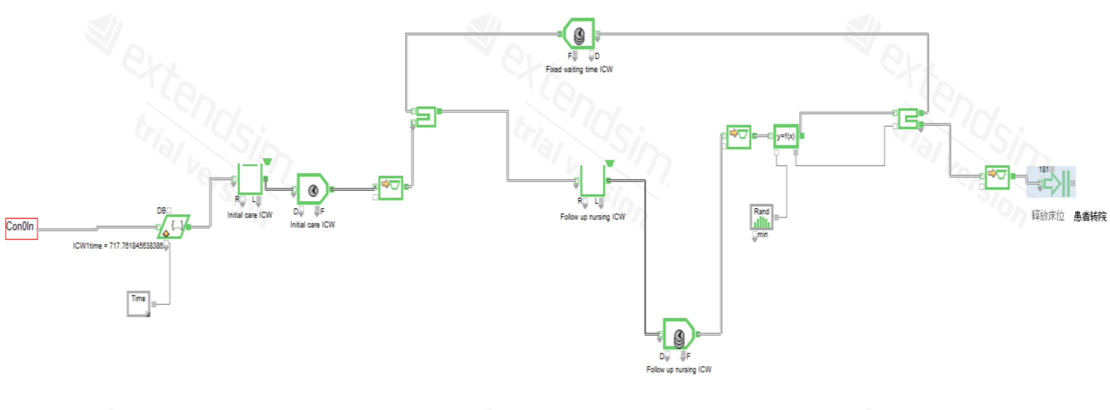


Figure 102: Modular composition of the interior of the ward

(2) Time acquisition

In this module, there are specific requirements for the length of time spent in the ward, all patients in the moderate injury ward will be discharged or transferred within 48 hours of admission, and all patients in the minor injury ward will be discharged within 24 hours of admission. For patients in ICU and CCU wards, a dictionary of data on the time they were cared for in the ward has been given. So here you need to get the time of the present as the time they have been in the ward

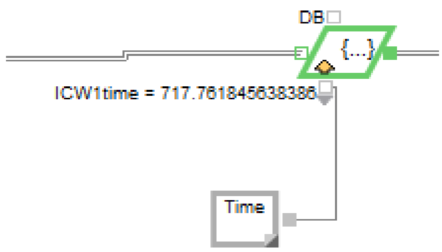


Figure 103: Get the Time module

Here you need to get the current time as the time they have been in the ward, and here are the specific settings

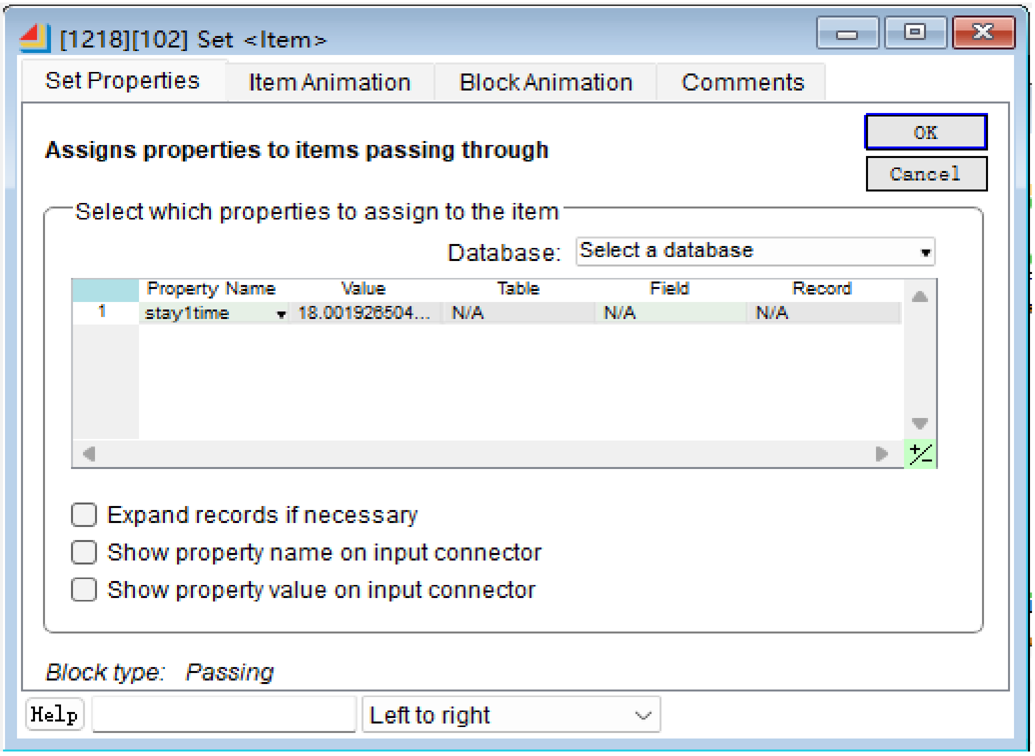


Figure 103: The settings for the present time acquisition

(3) Initial care process module

The module is mainly composed of resource waiting, initial care activities, and resource release, and the module diagram and specific settings are as follows

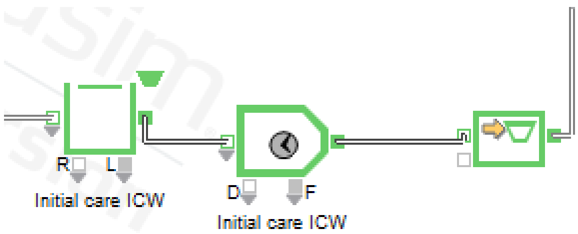


Figure 104: Initial Care Process Module

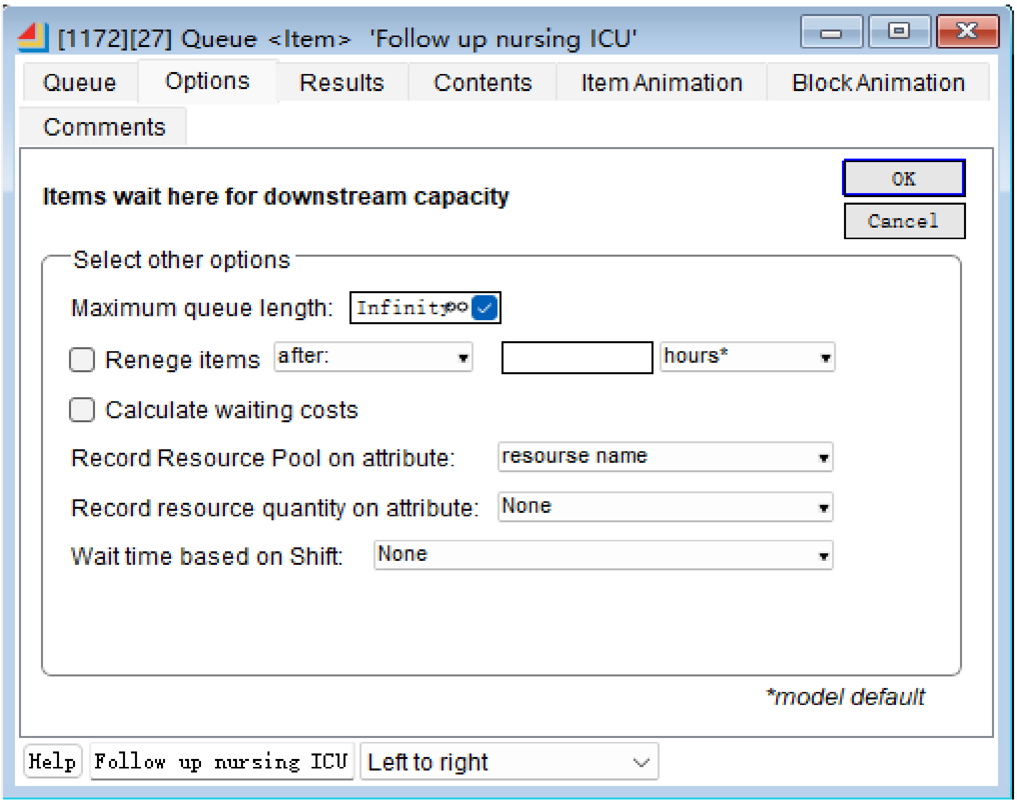


Figure 105: Initial acquisition of resources

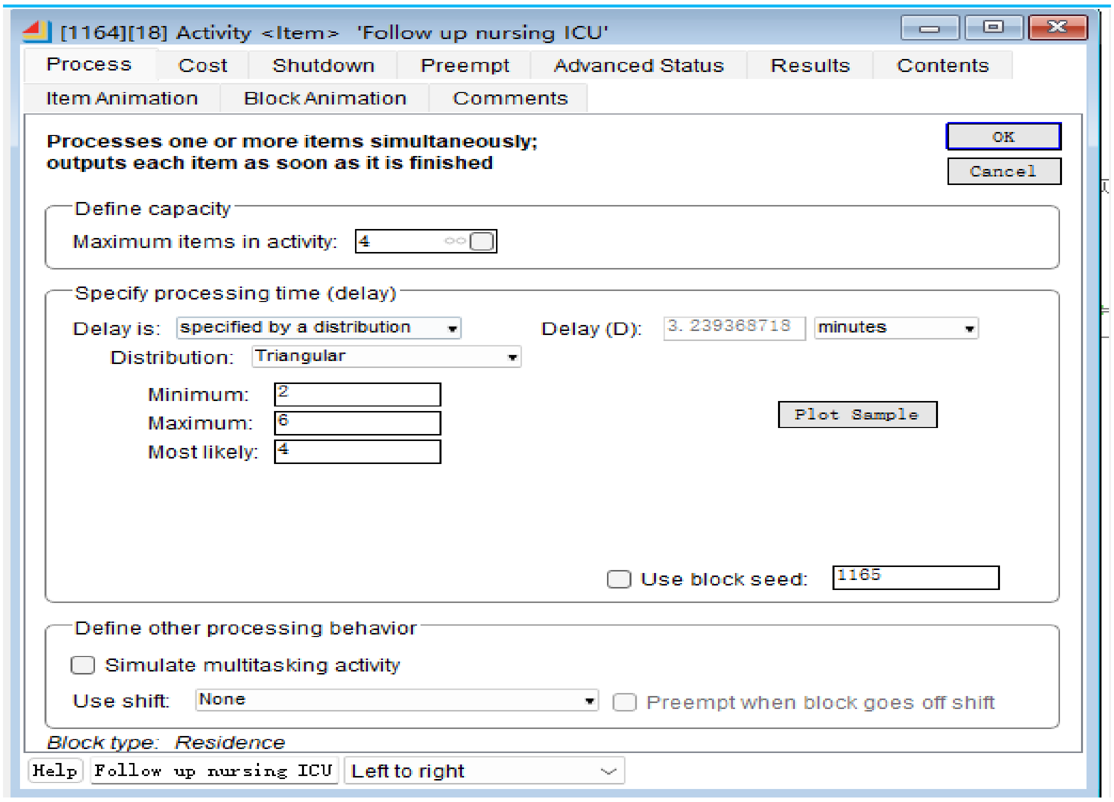


Figure 106: Initial duration of care

(4) Follow-up care module

Since the patient has a time limit in the ward and follow-up care needs to be done at regular intervals, it is assumed that the patient stays in the ward after the initial care and continues to do the corresponding follow-up care until the end of the time.

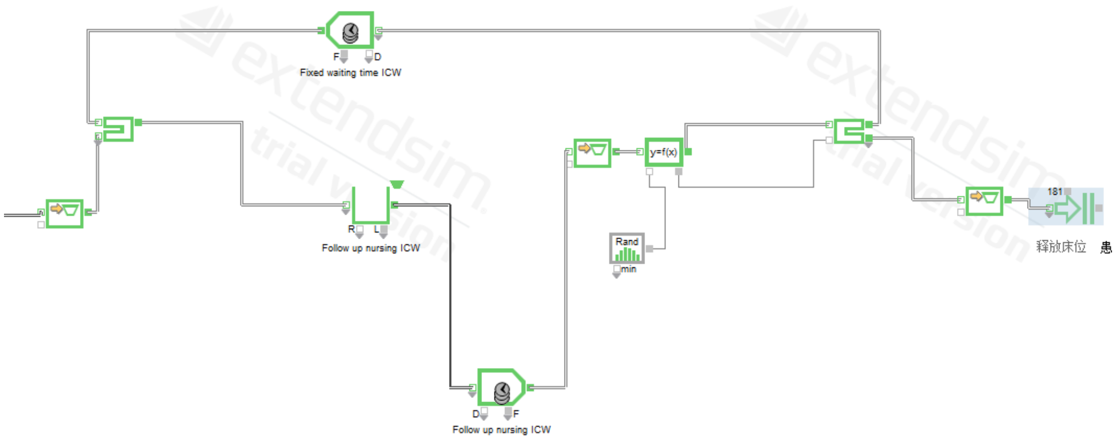


Figure 107: Follow-up care module

In this module, the first follow-up care is first experienced, and the module setup is similar to the initial care, but the specific parameters are different

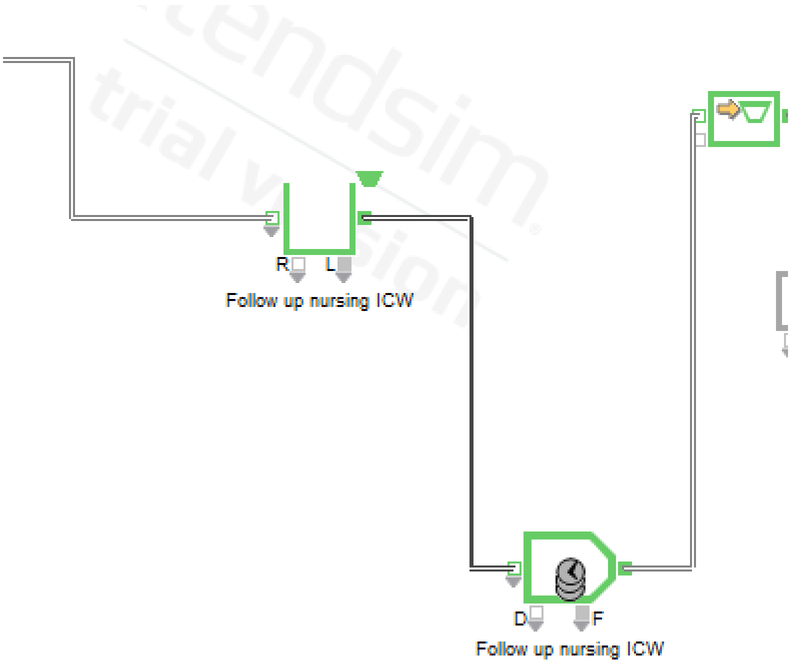


Figure 108: First follow-up care

This is followed by a module that determines whether to enter the circulation or leave the ward

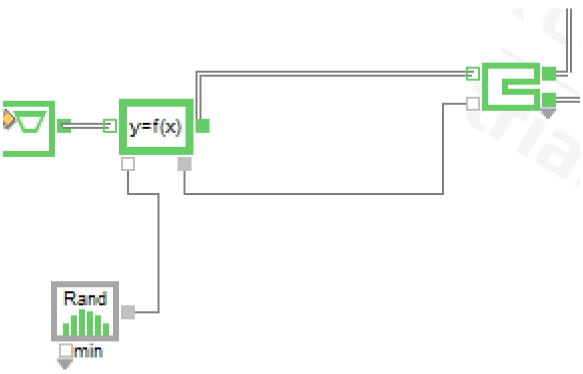


Figure 109: Judgment module

The specific judgment code equation is as follows, subtract the time the patient stays in the ward from the current time to see if it is greater than the time specified in the question, if it is not greater, continue to enter the cycle, otherwise leave the hospital.

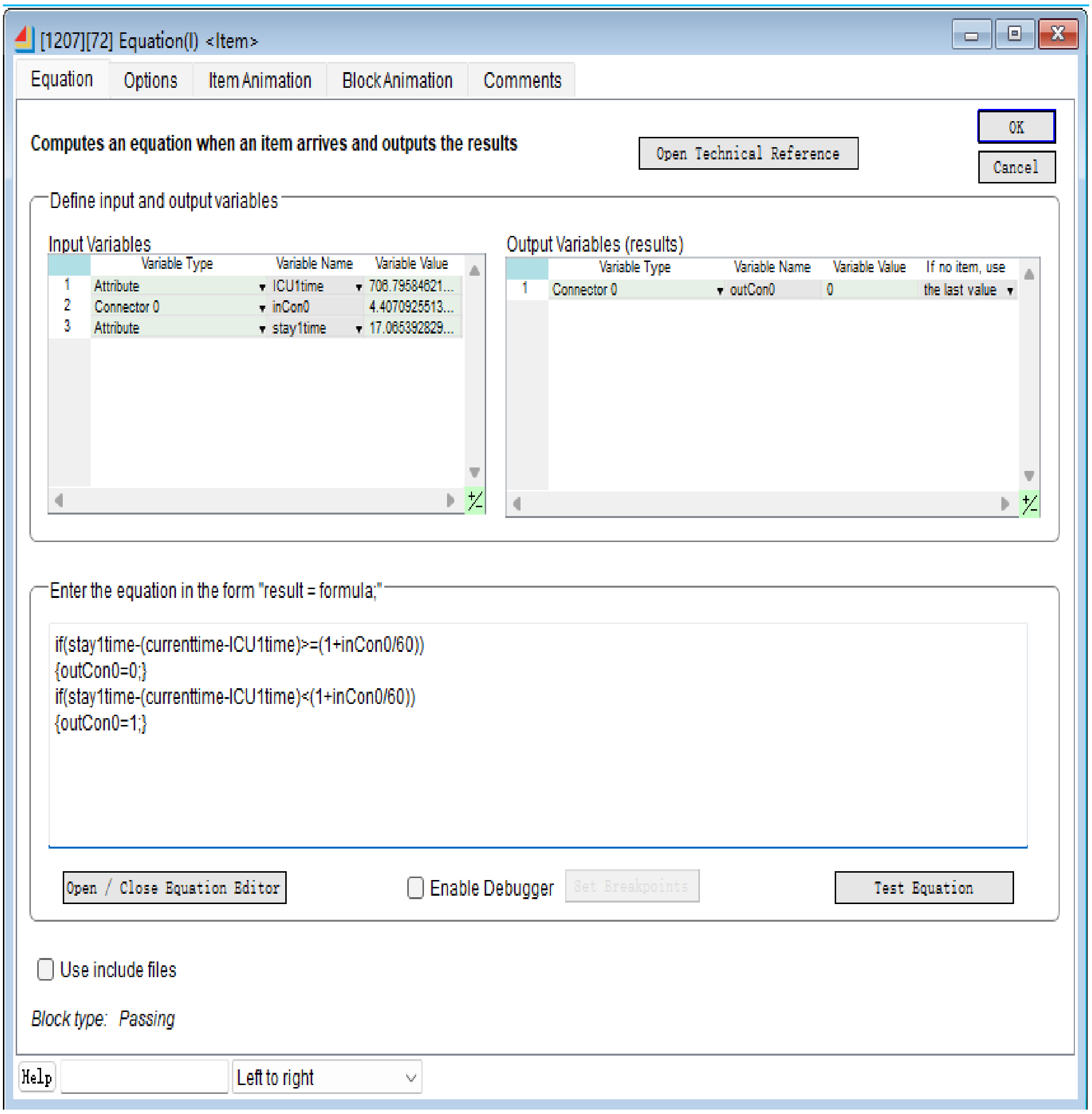


Figure 110: Judgment code

Because each patient's follow-up care needs to be done every 1 hour or 4 hours, for each of them, they need to wait 1 hour or 4 hours at a time to cycle through follow-up care.

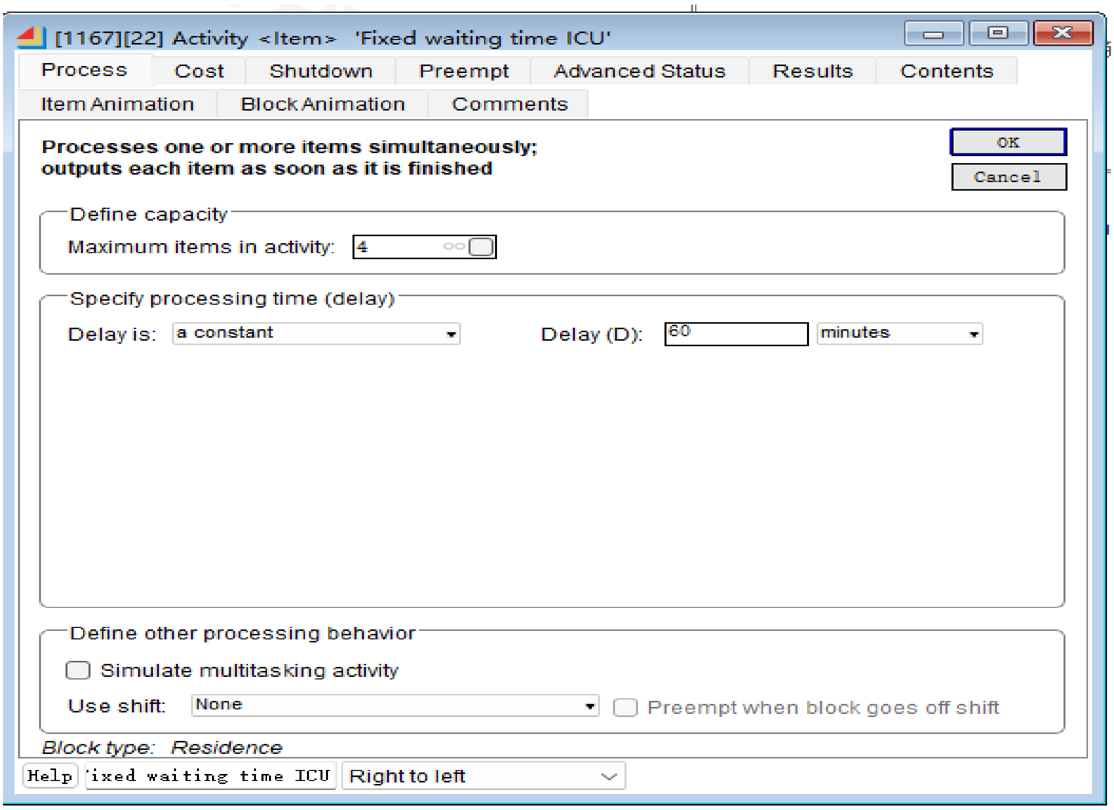


Figure 111: The time required to wait while looping

If the time to stay in the ward is up, leave the ward and be shunted to transfer or discharge (for minor injuries)

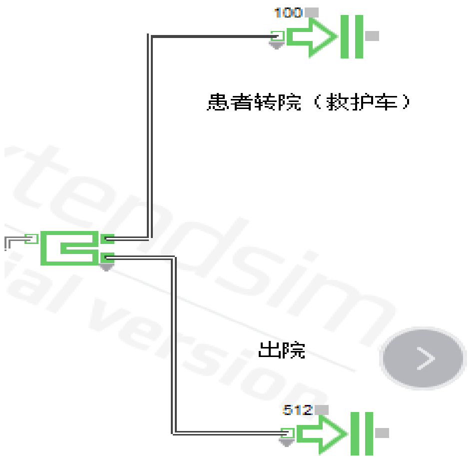


Figure 112: Ward triage

4 Analysis of results

4.1 Detailed answers to questions and analysis of data against the model

4.11 Question 1 of Phase 1

Phase 1: Current operations of the field hospital

1. **Is the current configuration of the field hospital adequate to handle the expected patient load? If not, give a reason.**

(1) Problem analysis

In terms of whether the load can be satisfied, that is, the speed at which the treatment for the patient can be completed is greater than the rate at which the patient flows in, that is, there will be no congestion, that is, the average passage time of the patient per tent will not increase with the increase of the simulation time, but will tend to a fixed value.

(2) Experimental design

By setting the time attribute value for each generated entity, the average time for each patient to pass through each tent is recorded, and then the reading statistics are carried out through the information module. The experiment was conducted based on an initial staffing arrangement without any optimization.

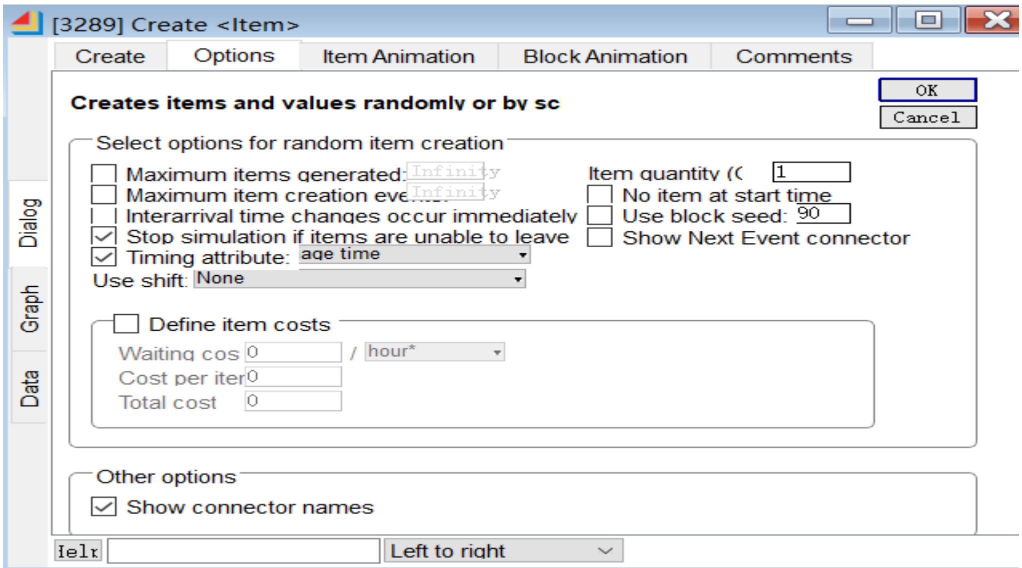


图 113：create

Use the clone button to drag out the final mean pass time results, making it more intuitive and easy to analyze

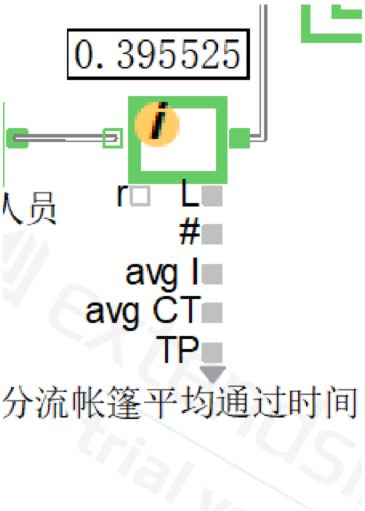


Figure 114: Divert tent average pass time module

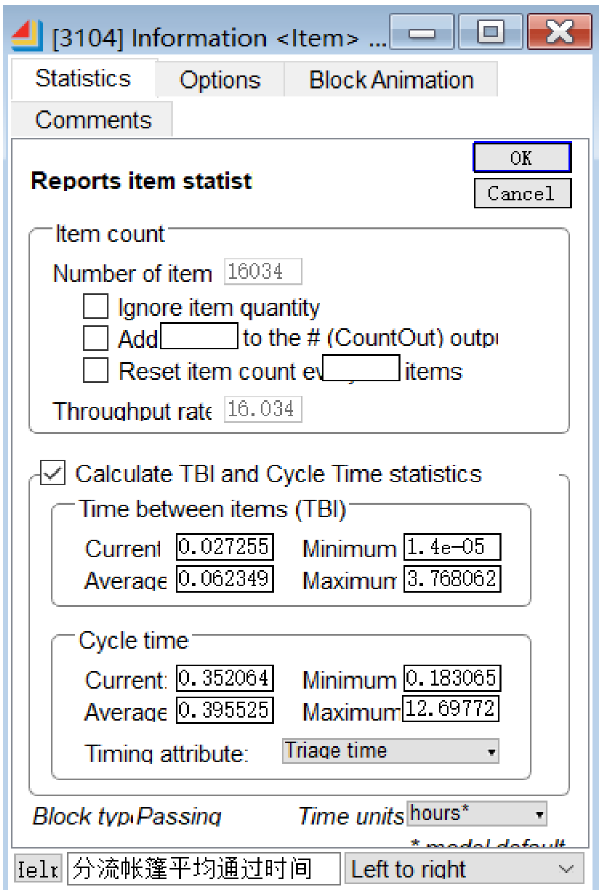


Figure 115: Diversion tent average pass time setting

The average transit time of each tent was cloned for comparative analysis

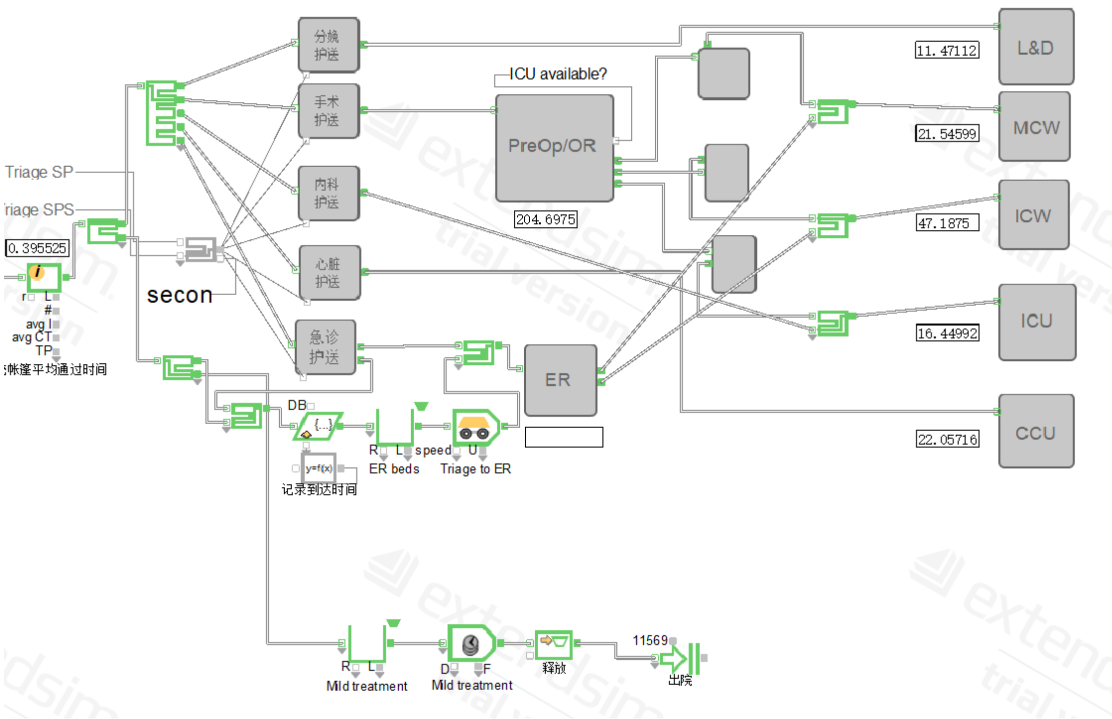


Figure 116: Average pass time for cloning

(3) Experimental execution

First of all, 240 hours of operation is set to 10 days, and then the time of each evaluation is observed and recorded for subsequent comparison.

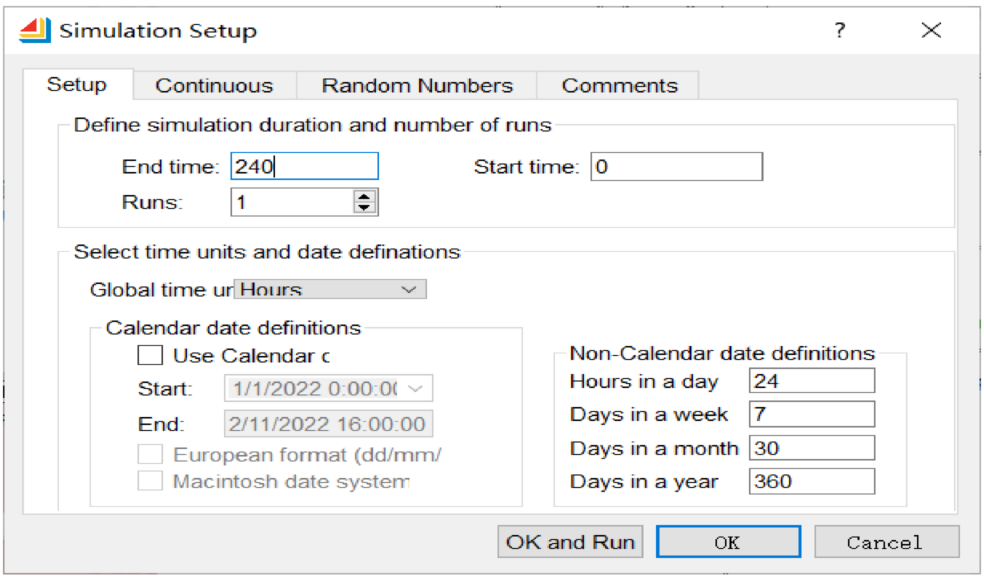


Figure 117: Experimental time settings

The data of 240 hours of simulation operation is obtained

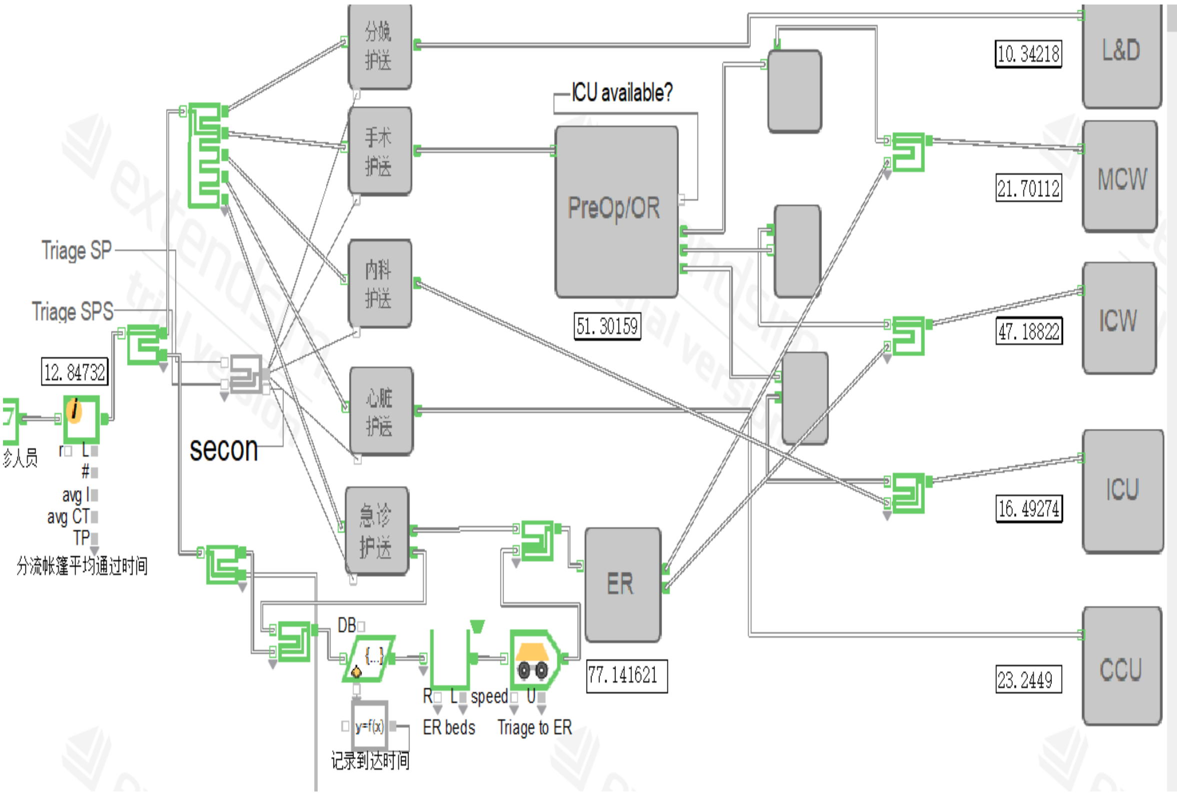


Figure 118: Average pass time per module

After that, the simulation was performed for an additional 720 hours.

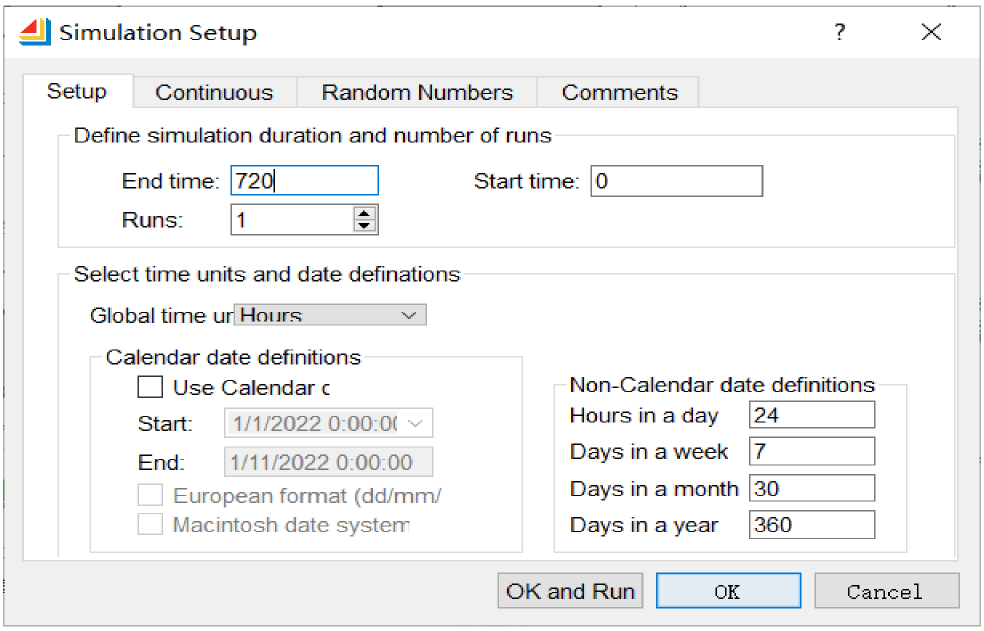


Figure 119: The setup time is 720 hours

With 720 hours of operation, it is evident that the passage time of the triage tents, anesthesia and operating rooms, and emergency rooms has increased several times, while there has been little significant change in the other tents.

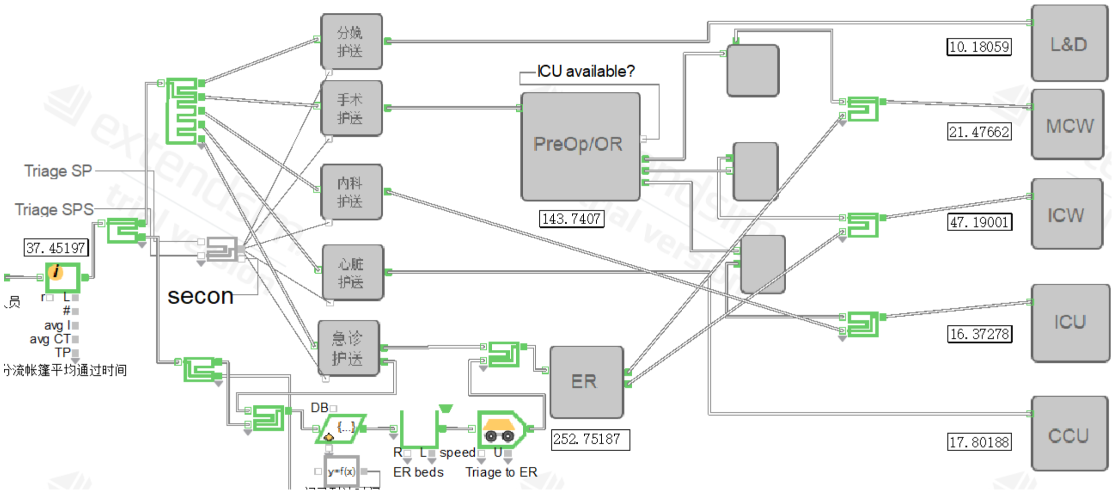
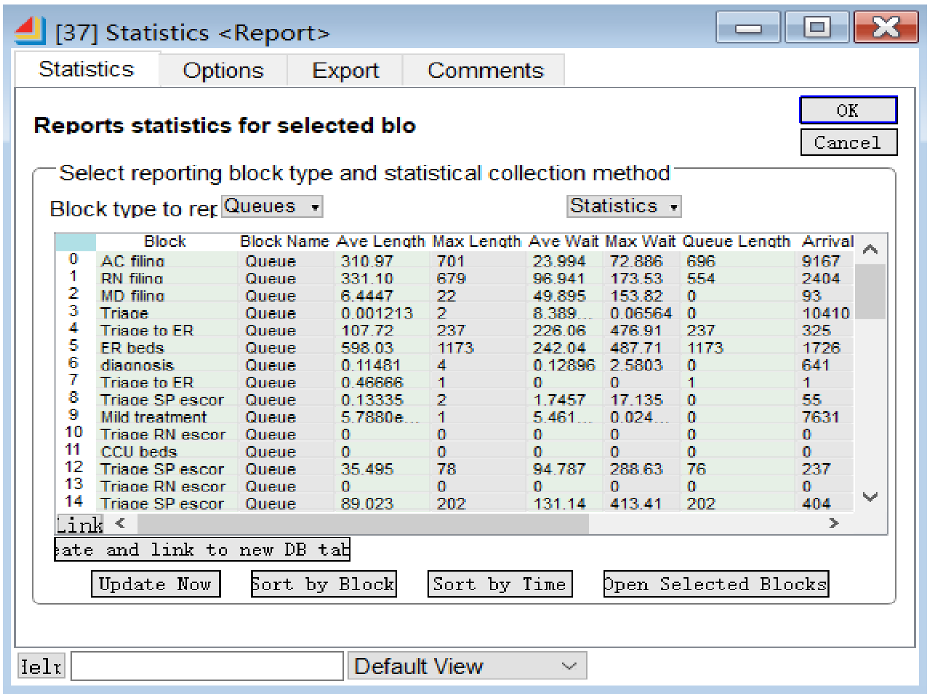


Figure 120: Results after setting to 720

(4) The conclusion of the problem

The field hospital was not sufficient to meet the patient load due to the obvious bottlenecks and congestion, and observational statistics showed that patients waited for more than 24 hours or even 242.04 hours, which was completely insufficient to meet the demand.



	Block	Block Name	Ave Length	Max Length	Ave Wait	Max Wait	Queue Length	Arrival
0	AC filing	Queue	310.97	701	23.994	72.886	696	9167
1	RN filing	Queue	331.10	679	96.941	173.53	554	2404
2	MD filing	Queue	6.4447	22	49.895	153.82	0	93
3	Triage	Queue	0.001213	2	8.389...	0.06564	0	10410
4	Triage to ER	Queue	107.72	237	226.06	476.91	237	325
5	ER beds	Queue	598.03	1173	242.04	487.71	1173	1726
6	diagnosis	Queue	0.11481	4	0.12896	2.5803	0	641
7	Triage to ER	Queue	0.46666	1	0	0	1	1
8	Triage SP escor	Queue	0.13335	2	1.7457	17.135	0	55
9	Mild treatment	Queue	5.7880e...	1	5.461...	0.024...	0	7631
10	Triage RN escor	Queue	0	0	0	0	0	0
11	CCU beds	Queue	0	0	0	0	0	0
12	Triage SP escor	Queue	35.495	78	94.787	288.63	76	237
13	Triage RN escor	Queue	0	0	0	0	0	0
14	Triage SP escor	Queue	89.023	202	131.14	413.41	202	404

Figure 121: Final report data

4.12 Question 2 of Phase 1

2. What are the current bottlenecks in field hospitals? (Consider staffing, layout, equipment, and any other bottlenecks you deem to be)

(1) Problem analysis

The bottleneck of the field hospital can be understood as the problem that makes the field hospital unable to meet the current patient load

Firstly, the tent with bottlenecks was found through the average passing time, and then the statistical module was used to count various data of each queue, activity, and patient flow, and the data were analyzed and sorted to find out where the bottlenecks were.

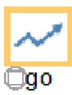
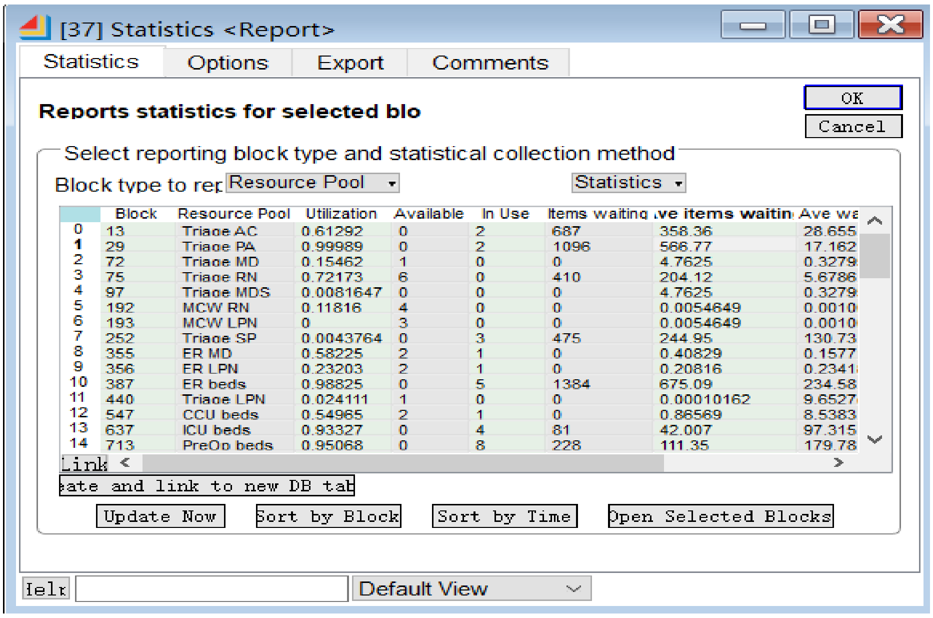


Figure 122: The Static module

(2) Experimental execution

In the previous question, the average tents were identified as triage tents, anesthesia and operating rooms, and emergency rooms based on the change in average pass time with simulation time. By taking a closer look at the resources of the three tents, the bottleneck is the one with the highest waiting time.



	Block	Resource Pool	Utilization	Available	In Use	Items waiting	ve items waitin	Ave wa
0	13	Triage AC	0.61292	0	2	687	358.36	28.655
1	29	Triage PA	0.99989	0	2	1096	566.77	17.162
2	72	Triage MD	0.15462	1	0	0	4.7625	0.3279
3	75	Triage RN	0.72173	6	0	410	204.12	5.6786
4	97	Triage MDS	0.0081647	0	0	0	4.7625	0.3279
5	192	MCW RN	0.11816	4	0	0	0.0054649	0.0010
6	193	MCW LPN	0	3	0	0	0.0054649	0.0010
7	252	Triage SP	0.0043764	0	3	475	244.95	130.73
8	355	ER MD	0.58225	2	1	0	0.40829	0.1577
9	356	ER LPN	0.23203	2	1	0	0.20816	0.2341
10	387	ER beds	0.98825	0	5	1384	675.09	234.58
11	440	Triage LPN	0.024111	1	0	0	0.00010162	9.6527
12	547	CCU beds	0.54965	2	1	0	0.86569	8.5383
13	637	ICU beds	0.93327	0	4	81	42.007	97.315
14	713	PreOp beds	0.95068	0	8	228	111.35	179.78

Figure 123: Average pass time in the report

Through the observation table, it was concluded that the waiting time of the PA in the triage tent reached 566.77, ranking first among all resources in this tent;

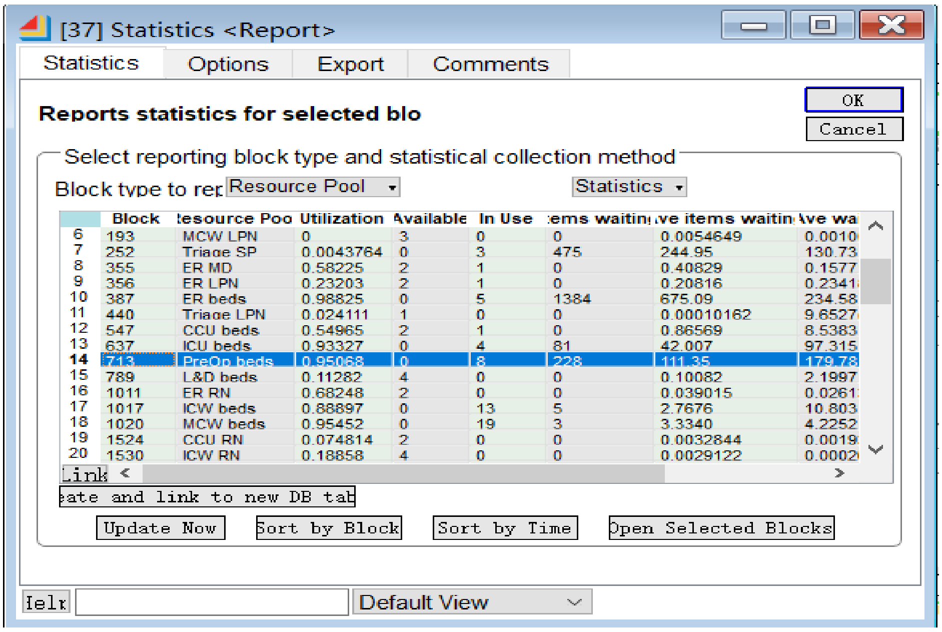


Figure 124: PA Waiting Ranks First

In the anesthesia room and operating room, the waiting time for beds reached 228 hours, ranking first in the tent.

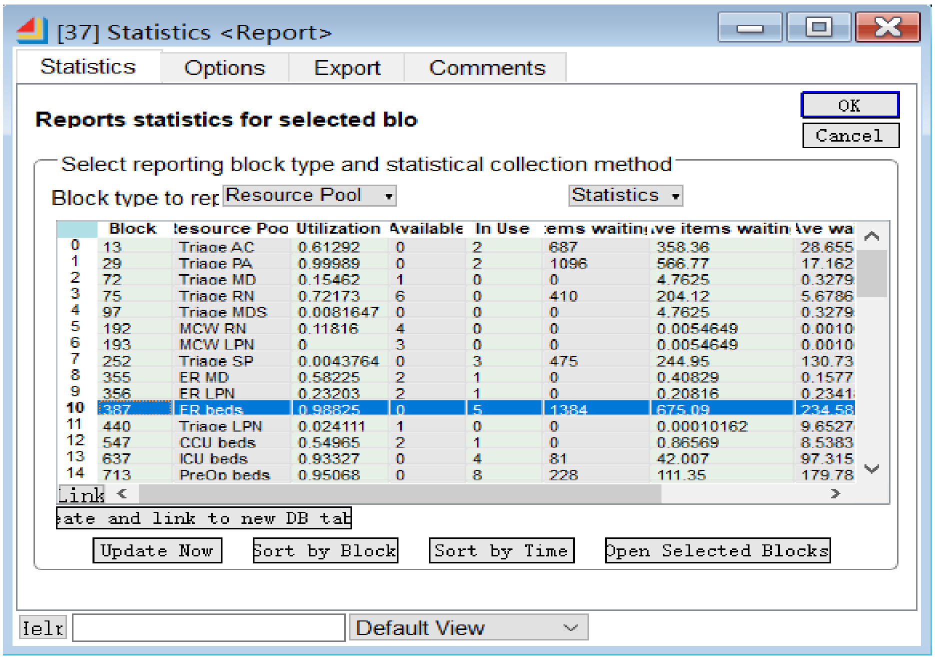


Figure 125: Beds in anesthesia and operating rooms are ranked first

In the emergency room, beds are also the main bottleneck, with waiting times of up to 675.09 hours

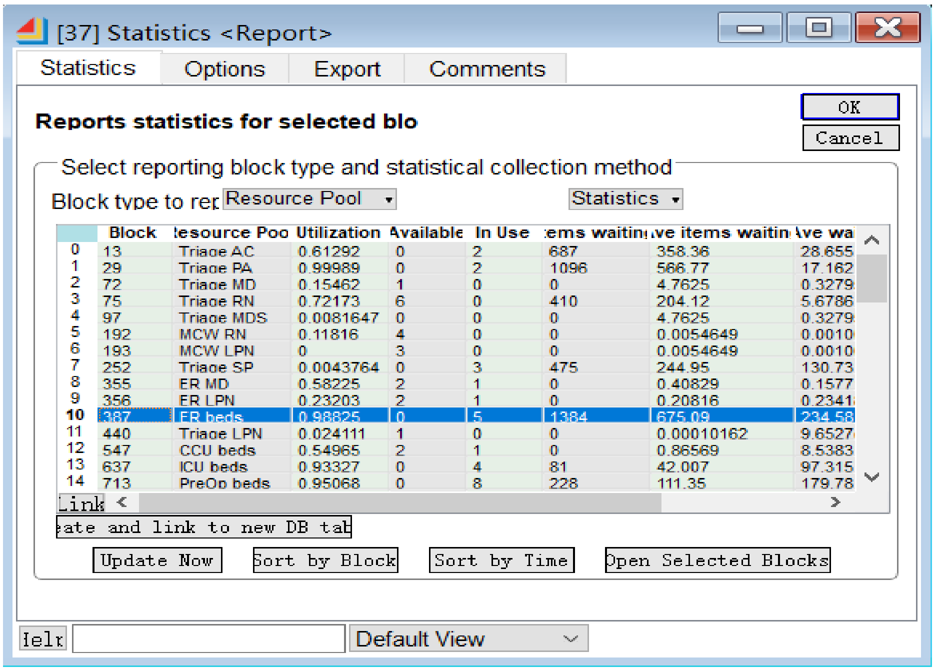


Figure 126: Waiting for emergency room beds also ranks highly

The layout is relatively reasonable by counting the flow of patients, and compared with the other problems mentioned above, the time difference is an order of magnitude, and does not constitute a bottleneck.

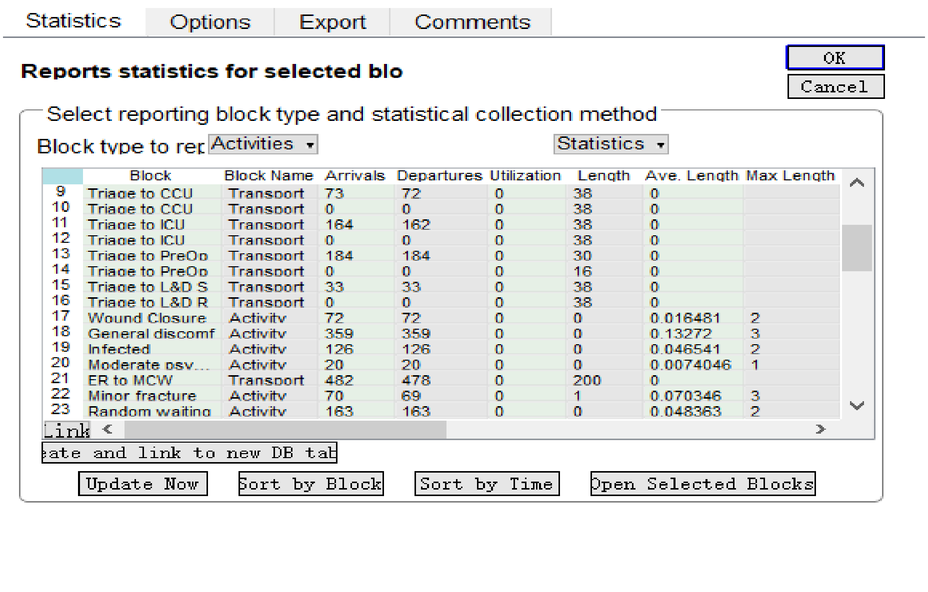


Figure 127: Other Data Wait Much Less

(3) Conclusion

The main bottlenecks are PAs in triage tents, beds in emergency rooms, and beds in anesthesia units, all of which are severely under-resourced to meet existing patient conditions.

4.13 Question 3 of Phase 1

3. How would you improve bottlenecks to improve field hospital operations? (Consider changing staffing, layout, equipment, and any other bottlenecks you deem to be, etc.)

(1) Problem analysis

In the previous question, the bottlenecks in the field hospital have been identified according to the statistical data, and the beds in the PA, emergency room and anesthesia room of the triage tent have been identified, and the existing bottlenecks have been analyzed and improved to find out the appropriate optimization plan. In addition to existing bottlenecks, reasonable further optimization and improvement, including staffing and facility placement, will be made in a way that does not increase costs. First, the experimental design and optimization are carried out based on the bottlenecks found now, and then the algorithm is optimized according to the layout.

(2) Experimental design for resource optimization

The number of runs (the value of the first run is 0) plus one input to the resource pool interface of PA is taken as the initial number of PAs, and then the number of consecutive runs is used as the X input, the average passage time of the triage tent is input Y, and the function image is drawn through the plotter scatter module to find the most suitable number of PAs, and the beds in the emergency room and anesthesia room are optimized using the same principle, and the average passage time of the tent is used as the reference benchmark for the optimization effect.

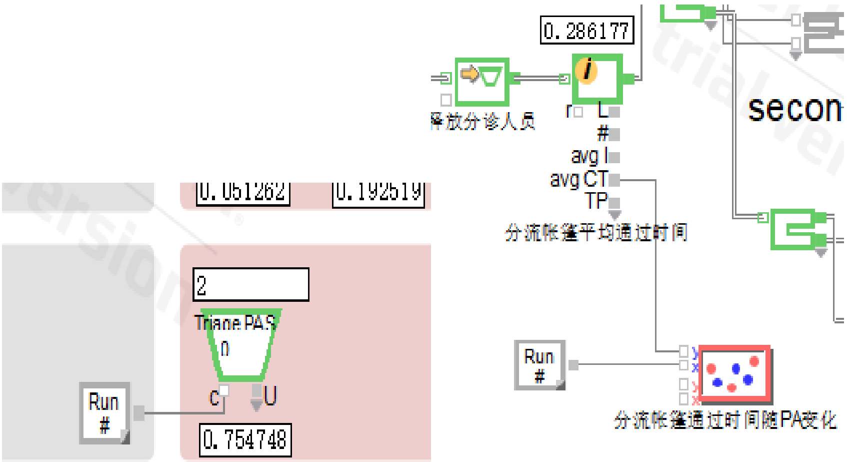


Figure 128: Average pass time in the model

(3) Experimental execution

Staffing and equipment optimization, PA in triage tents is based on the number of runs plus one as the initial value, and beds in the emergency room and anesthesia unit are added to the pre-optimization initial value.

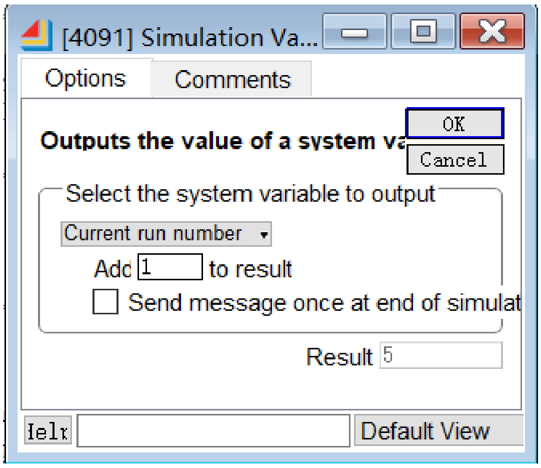


Figure 129: Setting the initial number

Run 5 times in a row, 240 hours each

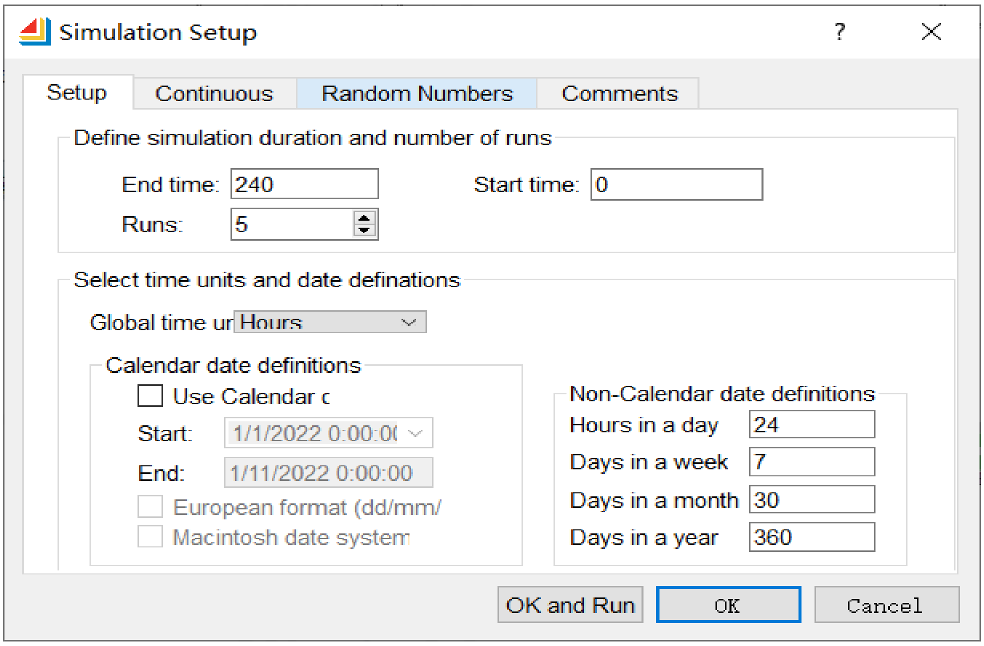


Figure 130: Setting the initial time

The relationship between the number of PAs and the passage time of the diversion tent is obtained, and it can be clearly observed that when the number of PAs in the diversion tent is 3, the marginal benefit is the largest, and the time decreases from more than 60 hours to less than 1 hour.

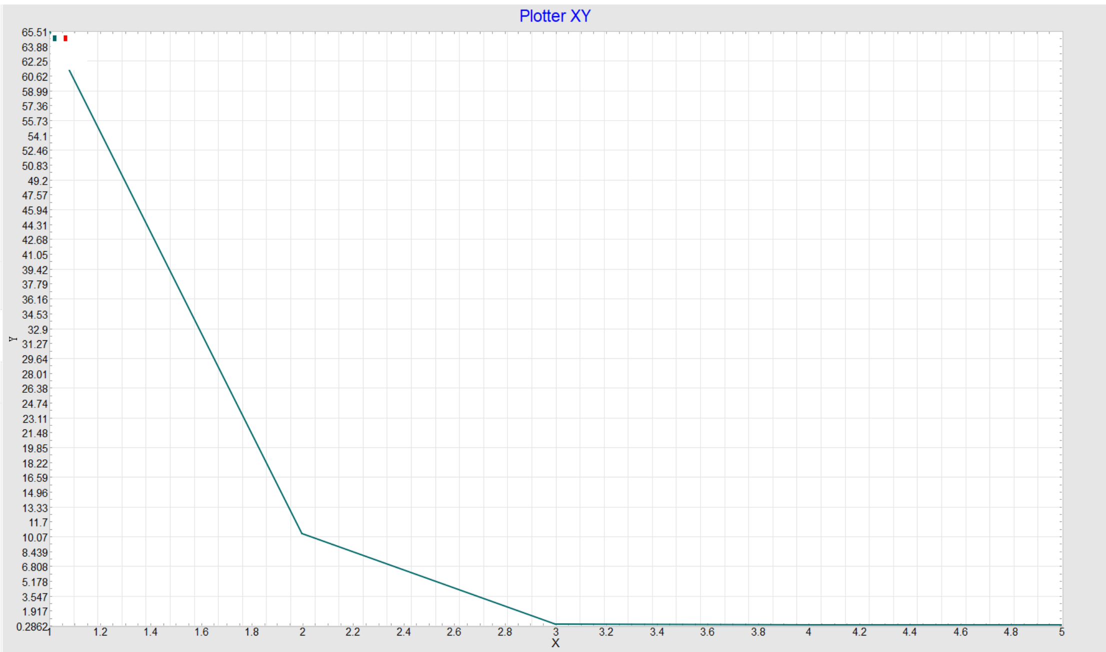


Figure 131: Graph of the number of PAs versus the passage time of the diversion tents

On the other hand, the passage time of the emergency room varies with the number of beds in the emergency room, and the waiting time becomes longer when the number of beds increases, indicating that the bottleneck is not only the number of beds, but also requires further experimental design.

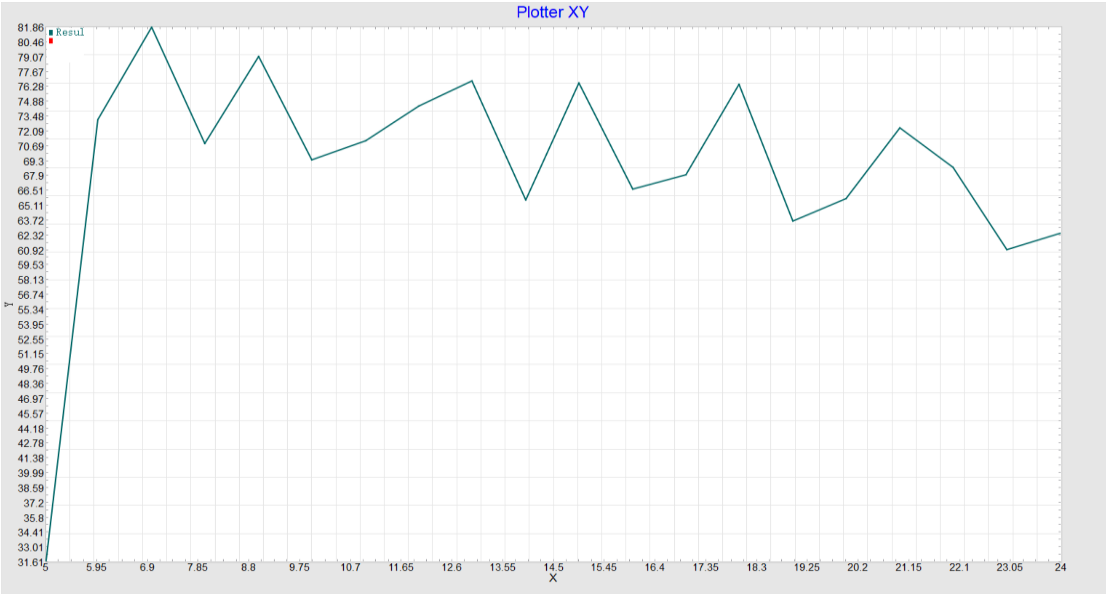


Figure 132: Emergency room throughput varies with the number of emergency room beds

The same is true for anesthesia room beds, and the waiting time for more beds has become longer, indicating that the bottleneck is still different.

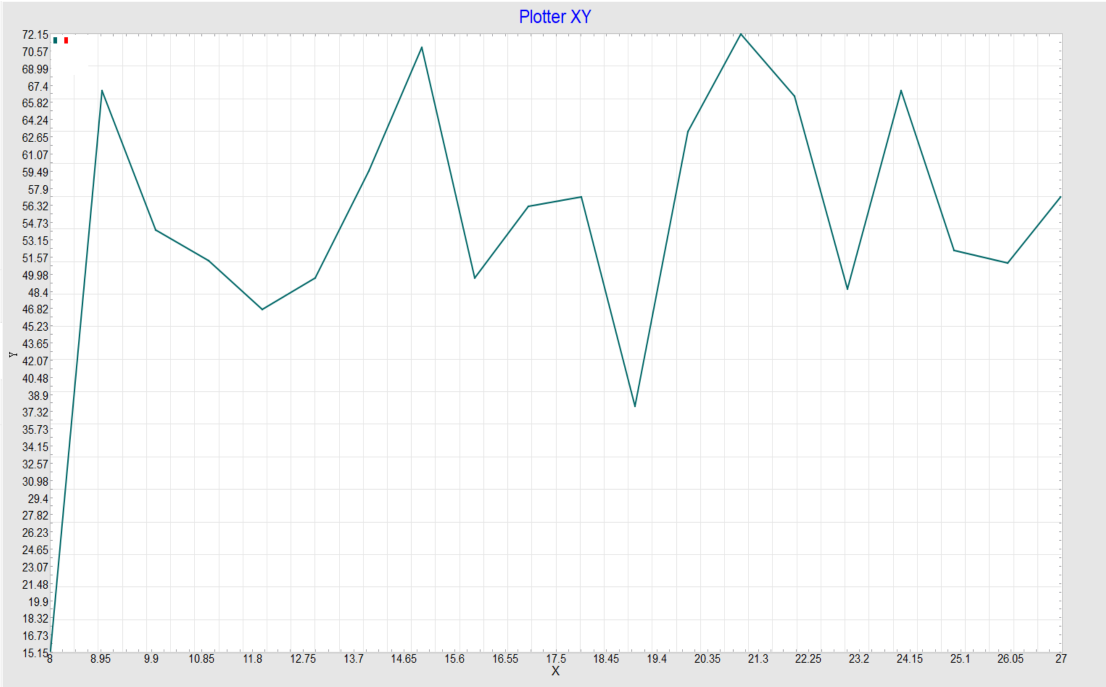


Figure 133: Waiting times have become longer as beds have increased

Further improved experiments were conducted to include the time spent waiting for MCW and ICW beds in the emergency room into the average pass time for MCW and ICW.

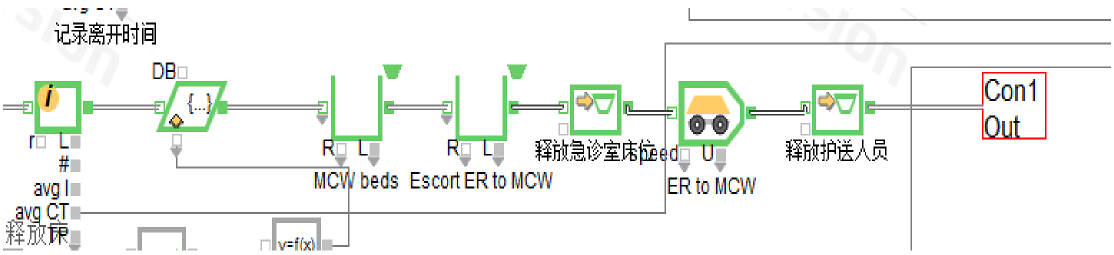


Figure 134: Modified average pass time

After 240 hours of simulation, it was found that the waiting time for ICW had increased significantly, indicating that ICW's bed capacity was also one of the bottlenecks.

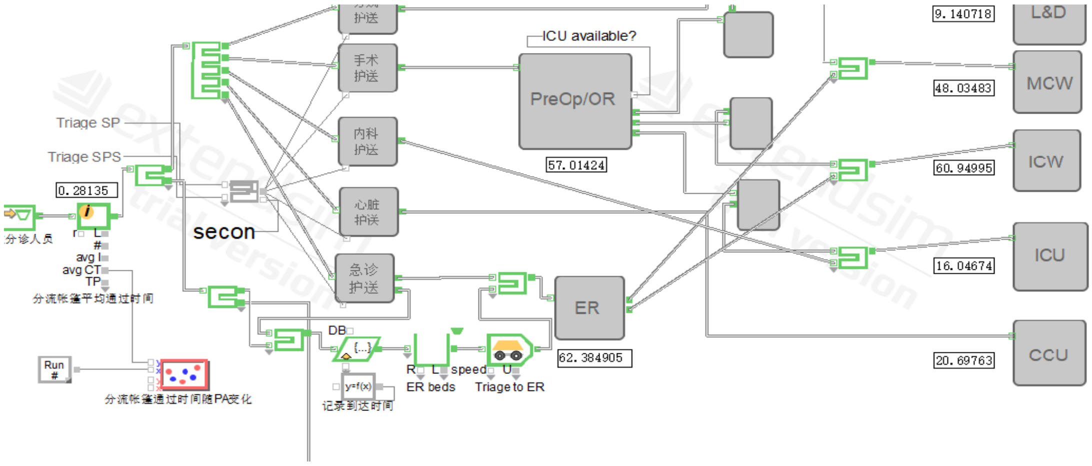
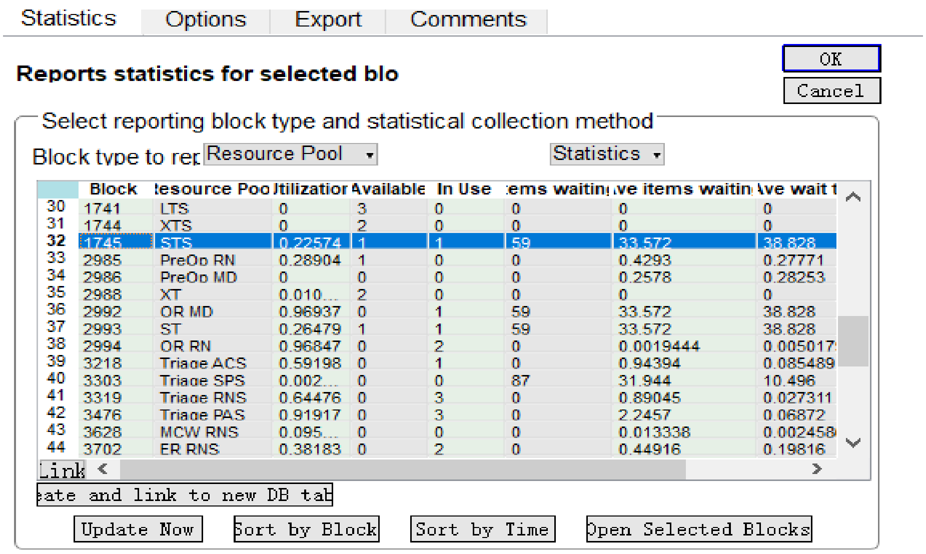


Figure 135: CW Wait Times Rise Dramatically

After improving the experiment, the statistical data were further observed to find out the resources with the longest waiting time except for the bed, and it was found that the waiting time of the surgeon, the operating room doctor, and the escort of the triage tent were all more than 30 hours.



	Block	Resource Poo	Utilizatior	Available	In Use	ems waitin	ve items waitin	Ave wait t
30	1741	LTS	0	3	0	0	0	0
31	1744	XTS	0	2	0	0	0	0
32	1745	STS	0.22574	1	1	59	33.572	38.828
33	2985	PreOp RN	0.28904	1	0	0	0.4293	0.27771
34	2986	PreOp MD	0	0	0	0	0.2578	0.28253
35	2988	XT	0.010...	2	0	0	0	0
36	2992	OR MD	0.96937	0	1	59	33.572	38.828
37	2993	ST	0.26479	1	1	59	33.572	38.828
38	2994	OR RN	0.96847	0	2	0	0.0019444	0.005017
39	3218	Triage ACS	0.59198	0	1	0	0.94394	0.085489
40	3303	Triage SPS	0.002...	0	0	87	31.944	10.496
41	3319	Triage RNS	0.64476	0	3	0	0.89045	0.027311
42	3476	Triage PAS	0.91917	0	3	0	2.2457	0.06872
43	3628	MCW RNS	0.095...	0	0	0	0.013338	0.002458
44	3702	ER RNS	0.38183	0	2	0	0.44916	0.19816

Figure 136: Other resources with the longest wait times

The optimal value of doctors in the operating room is 3

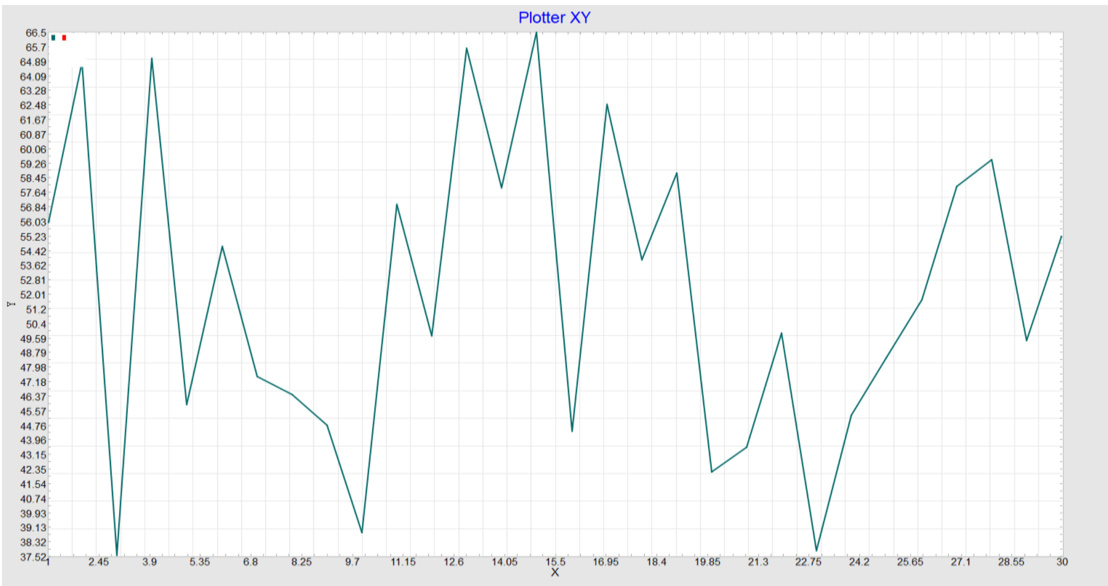


Figure 137: The optimal value for operating room physicians was found to be 3

The number of SPs in the triage tent seems to be the optimal, 9, but the actual situation is related to the number of beds due to the resource waiting, and if there is no free bed, the staff cannot escort and must wait together, and the final result needs to be analyzed in combination with the beds.

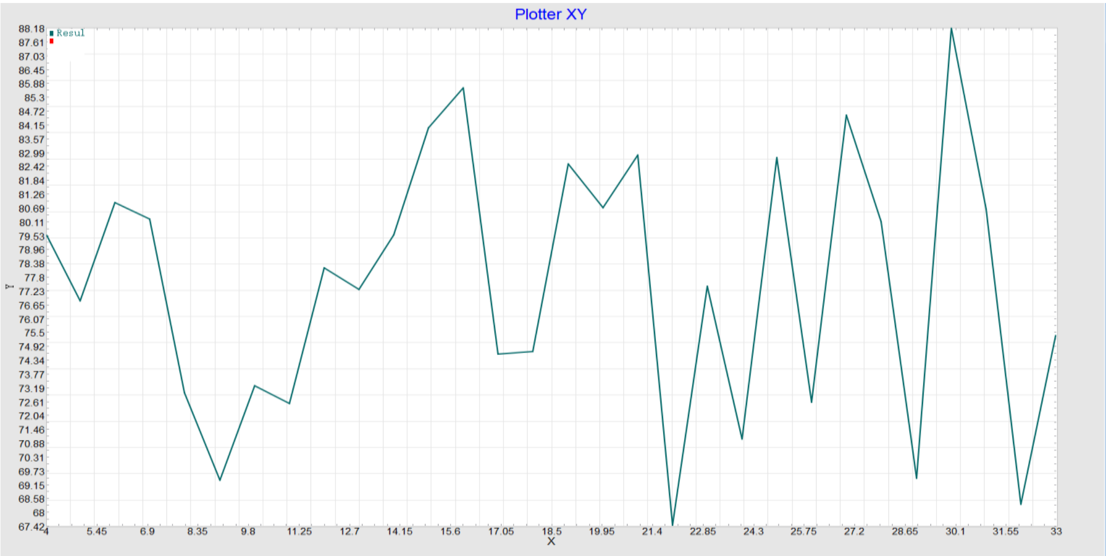


Figure 138: The best on the chart is 9

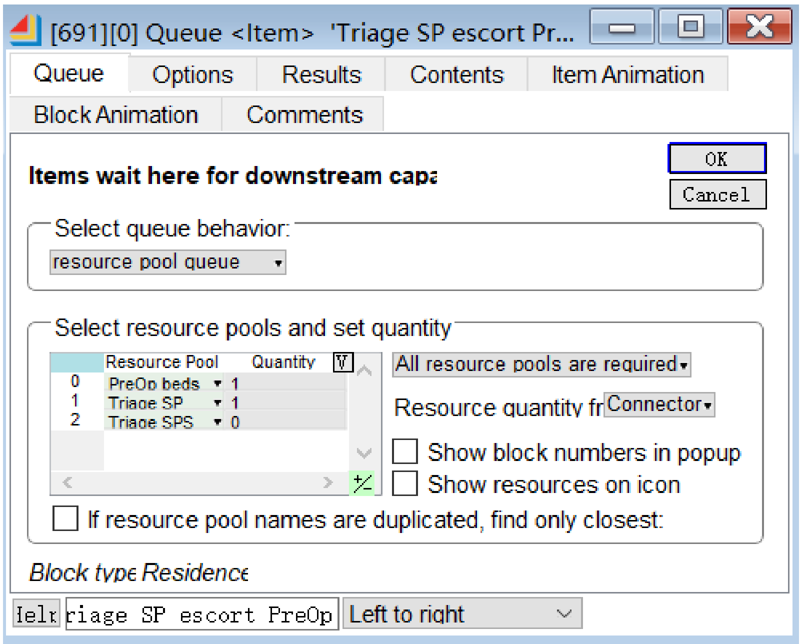


Figure 139: Resources for anesthesia rooms and triage tents

The optimal number of ST players is three, and at this point, the resources suspected of being bottlenecks have been determined

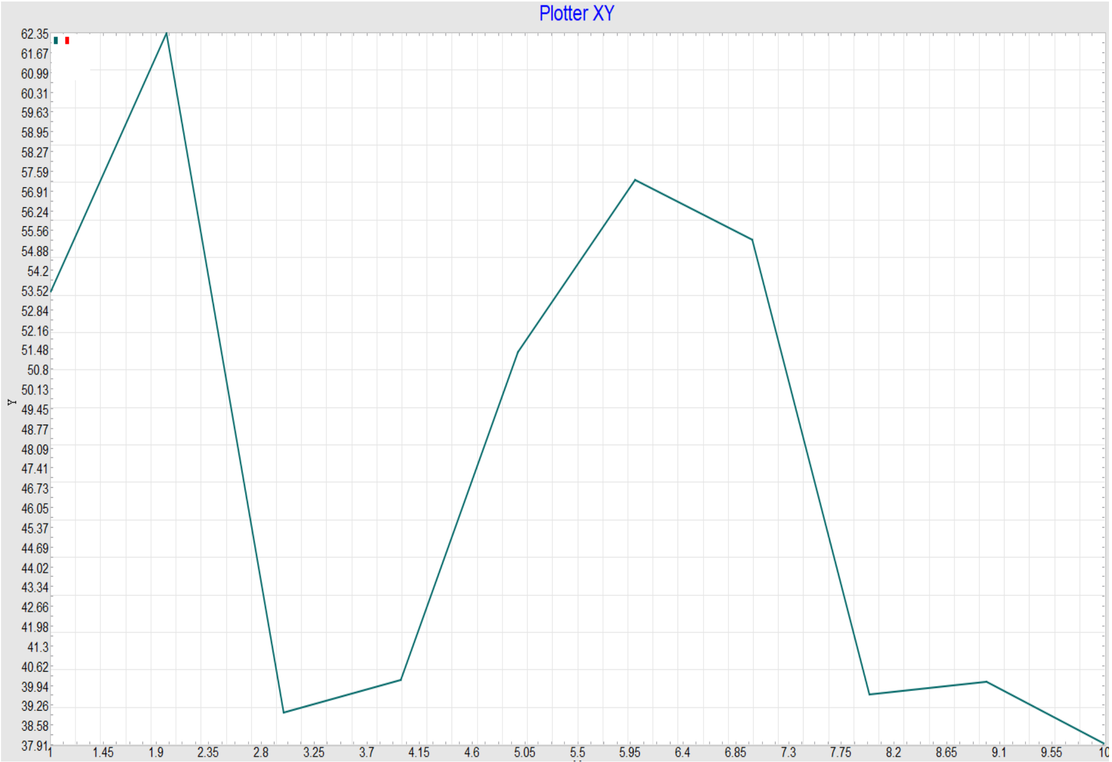


Figure 140: The optimal number of ST players is three

After the suspected bottleneck was eliminated, the variation curve of the passage time of the anesthesia room with the number of beds in the anesthesia room was re-simulated, and the optimal number of beds was 22

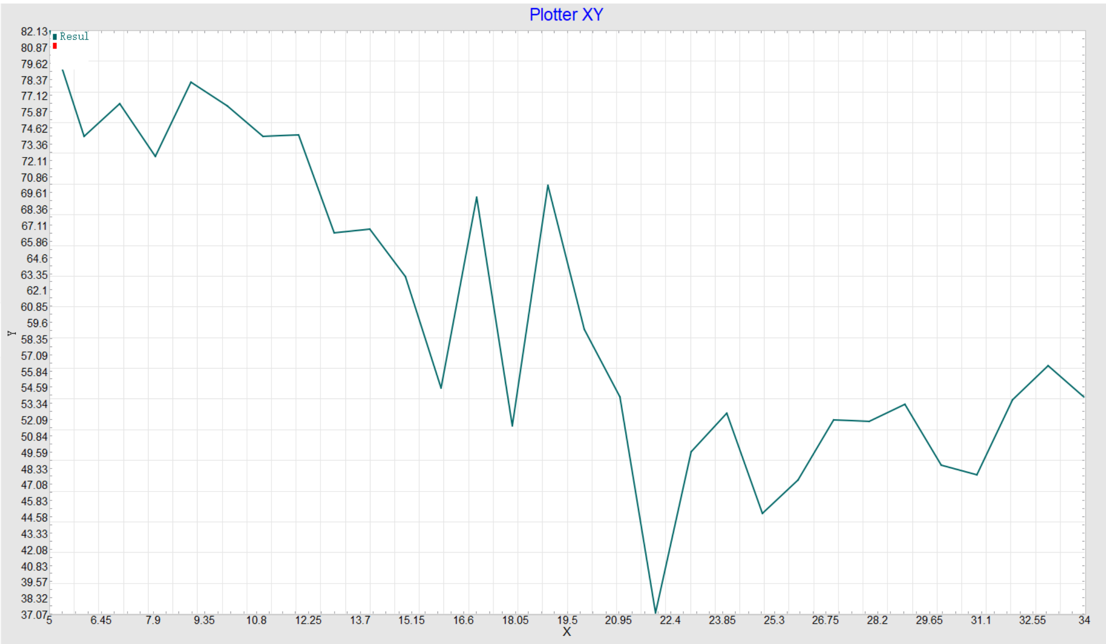


Figure 141: The optimal number is 22 beds

The emergency room is optimally arranged with 18 beds, and the average throughput time of the emergency room is minimal.

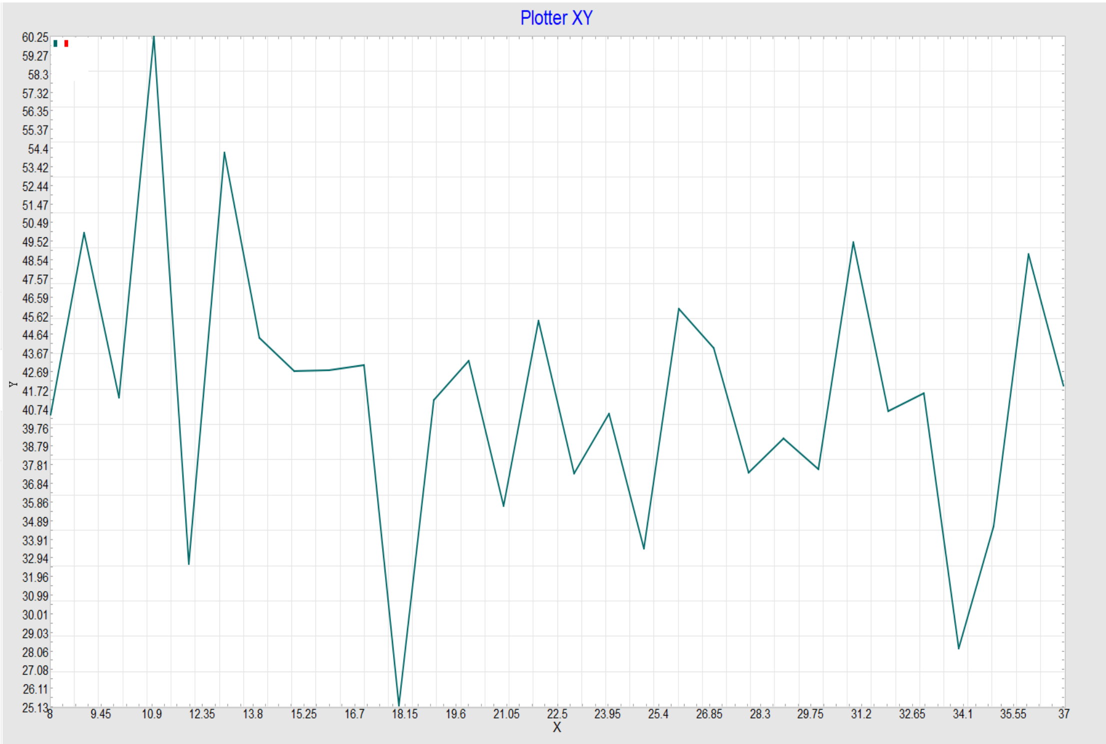


Figure 142: 18 beds are optimally furnished

The final optimization result is shown in the figure

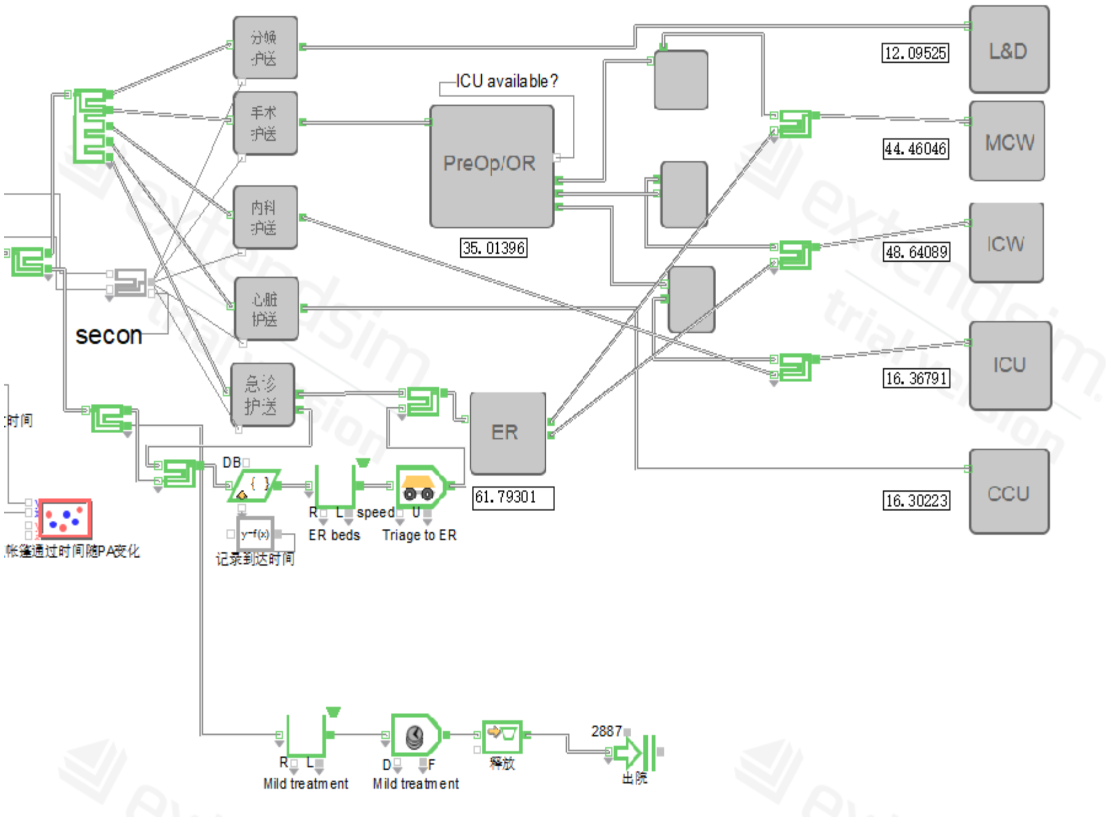


Figure 143: Final optimization result model

The final resource change is shown in the figure

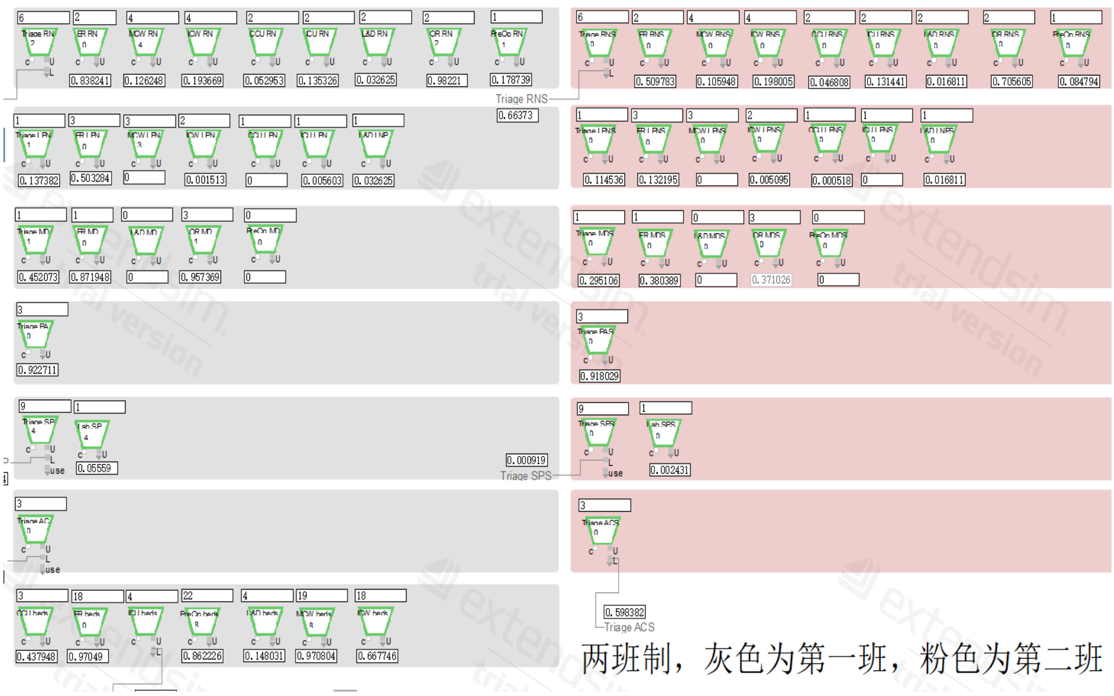


Figure 144: Final resource change

(4) Initial layout

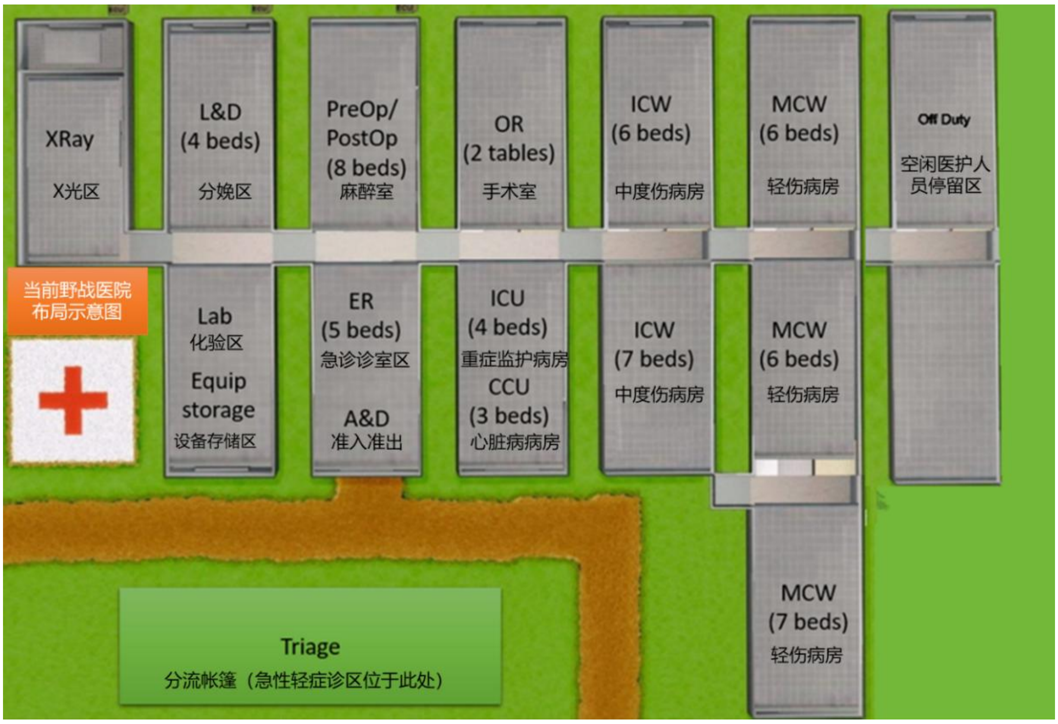


Figure 145: Initial layout diagram

(5) Layout optimization ideas

The layout is optimized according to the logistics SLP method. SLP, or System Layout Design, is a facility planning method. Firstly, according to the patient transportation volume in each facility in the model, the traffic volume is determined from the table, and then the level between each facility is divided by the table from the table, and finally the logistics related diagram is divided by the level, and the final layout modification is carried out

(6) Initial data of volume

15	Triage to L&D S	Transport	33	33	0	38	0		
16	Triage to L&D R	Transport	0	0	0	38	0		
17	Wound Closure	Activity	69	69	0	0	0.01583	2	0.21616
18	General discomf	Activity	293	293	0	0	0.10931	4	0.2810
19	Infected	Activity	98	98	0	0	0.036074	3	0.28392
20	Moderate psy...	Activity	19	19	0	0	0.0069968	1	0.25226
21	ER to MCW	Transport	391	391	0	200	0		
22	Minor fracture	Activity	79	78	0	1	0.078164	3	0.70555
23	Random waiting	Activity	162	162	0	0	0.04814	2	0
24	Follow up nursi	Activity	2622	2622	0.060642	0	0.24257	3	0.071037
25	Fixed waiting t	Activity	2460	2456	0.85326	4	3.4131	4	1
26	Initial care IC	Activity	166	166	0.041146	0	0.041146	1	0.19053
27	ER to ICW	Transport	93	93	0	200	0		
28	Preoperative pr	Activity	191	191	0	0	0.078726	1	0.39168
29	test	Activity	33	33	0	0	0.0057247	1	0.13609

Figure 146: Traffic data in the report

30	Lab to L&D	Transport	33	33	0	30	0		
31	Awaiting delive	Activity	33	33	0.065679	0	0.26272	2	3.3278
32	deliver babies	Activity	33	33	0.0047487	0	0.018995	1	0.55609
33	Recovery pre...	Activity	33	33	0.041256	0	0.16502	2	3.8604
34	Baby stay time	Activity	33	33	0.041256	0	0.16502	2	3.8604
35	Random waiting	Activity	70	70	0	0	0.024486	1	0
36	Follow up nursi	Activity	1104	1104	0.02548	0	0.10192	3	0.060682
37	Fixed waiting t	Activity	1034	1033	0.35893	1	1.4357	3	1
38	Initial care CC	Activity	71	71	0.01665	0	0.01665	1	0.095536
39	PreOp to X-ray	Transport	34	34	0	200	0		
40	X-ray	Activity	34	34	0	0	0.0070962	2	0.14794
41	PreOp to MCW	Transport	81	81	0	28	0		
42	Postoperative r	Activity	188	188	0.043178	0	0.34542	2	1.2150
43	PreOp to surger	Transport	191	191	0	28	0		
44	operation	Activity	189	188	0.3367	1	0.67339	2	2.8216

Figure 147: Volume data in the report

(7) The volume is from the table

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	Instructors	Yu Pingxiang	LAB	PREOP	CCU	Name of the college	MCW	Faculty of Mathematics and Informatics	Professional name

TR		Paper submission date		July 20, 2022	73	14			33
ER						93	391		
LAB				34					33
PRE OP						2	100		
SU				188					

Table 1: Volumes from to table

Or A, E, I, O grades, and their respective proportions are 1:2:3:4, as shown in Table 2

序号	作业对	强度	等级
1	TR--ER	558	A
2	ER--MCW	391	E
3	PO--SU	191	E
4	TR--PO	191	E

5	TR--ICU	164	I
6	PO--ICW	100	I
7	PO--MCW	81	I
8	TR--CCU	73	I
9	LAB--PO	34	O
10	TR--LD	33	O
11	LAB--LD	33	O
12	PO--ICU	2	O

Table 2: Classification levels

(8) Logistics related diagrams

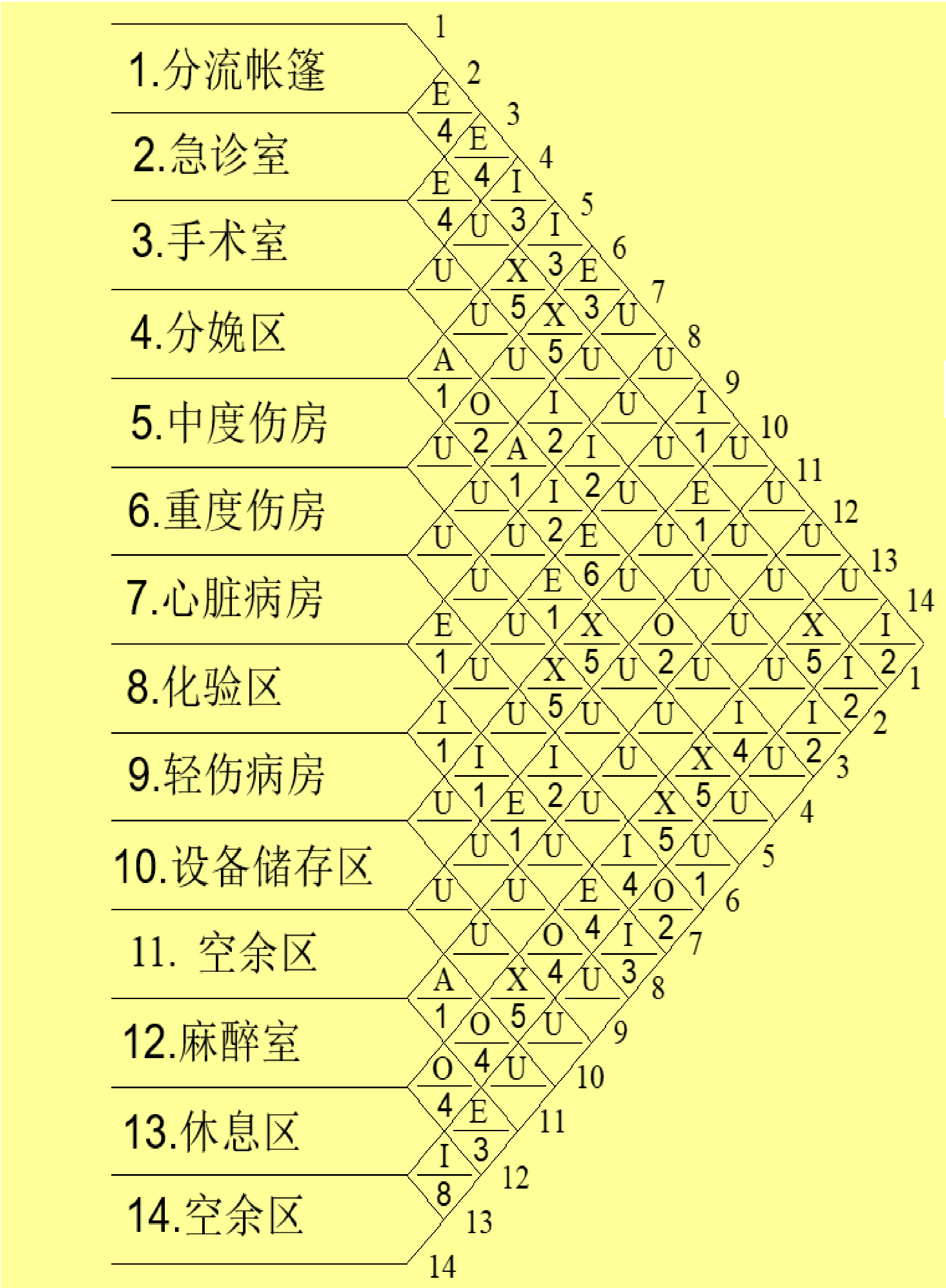

Figure 148: Logistics-related diagram

(9) Job sorting table

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作业	得分	排序
分流帐篷	12	1
麻醉室	12	2
急诊室	6	3
轻伤病房	4	4
手术室	3	5
化验室	2	6
分娩区	2	7
重伤病房	2	8
心脏病房	2	9
中伤病房	2	10

Table 3: Job Sorting Table

The assignment sorting table can finally lead to an improved layout diagram in which the locations of the laboratory area, anesthesia room and emergency room are adjusted

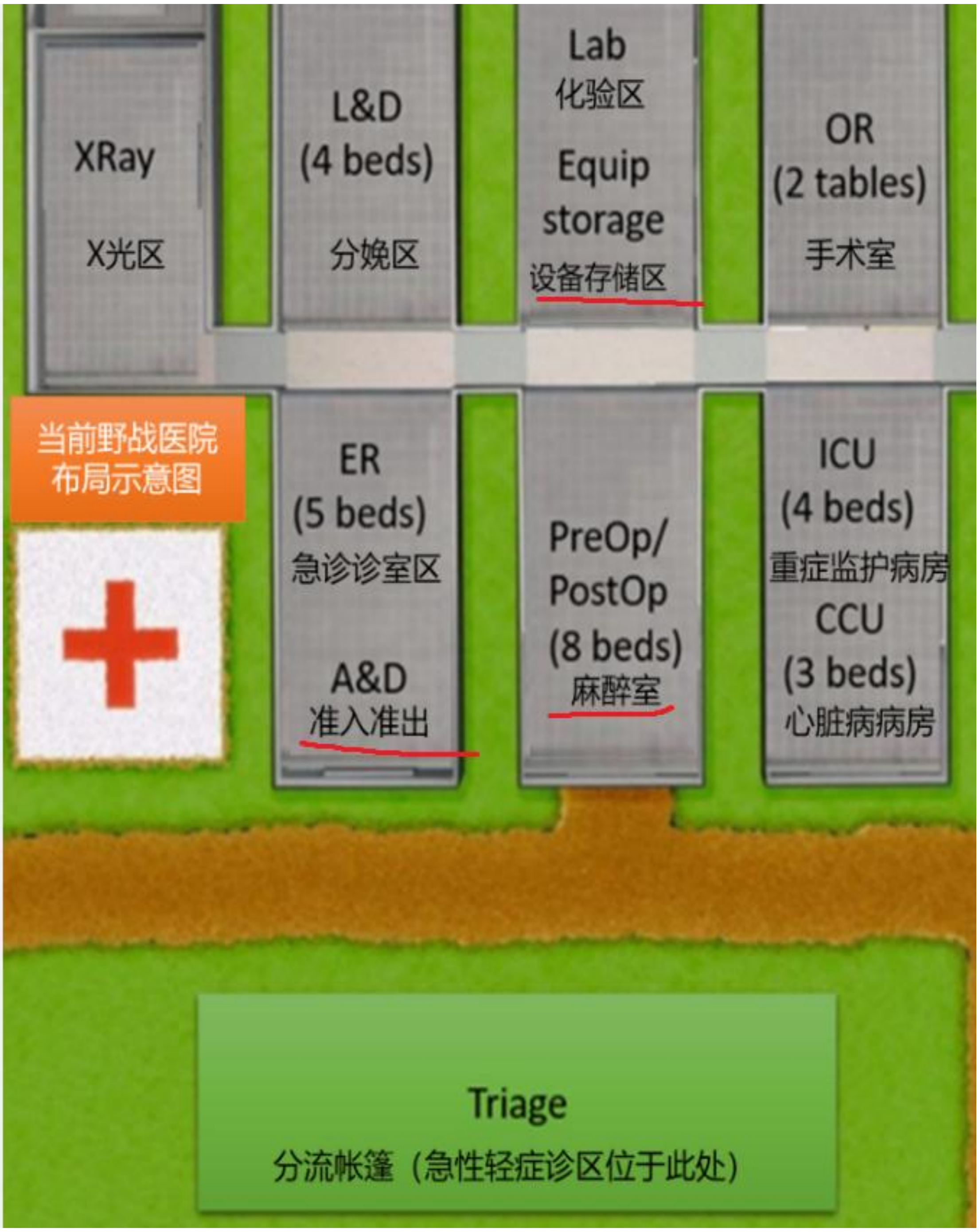


Figure 149: Final layout optimization diagram

4.14 Question 4 of Phase 1

4. If a hospital has overcapacity, how would you change the hospital configuration and reduce the number of resources accordingly?

(1) Problem analysis

Overcapacity is reflected in the existence of personnel and equipment that are underutilized, and it is enough to improve and optimize this phenomenon.

(2) Experimental design

By observing the resources whose utilization rate is less than 0.05 and the number is greater than 1 in the statistics, it is defined as a redundant resource pool. Adjust personnel changes for redundant resource pools, and further observe the optimized resource waiting time and utilization changes to evaluate the adjustment results.

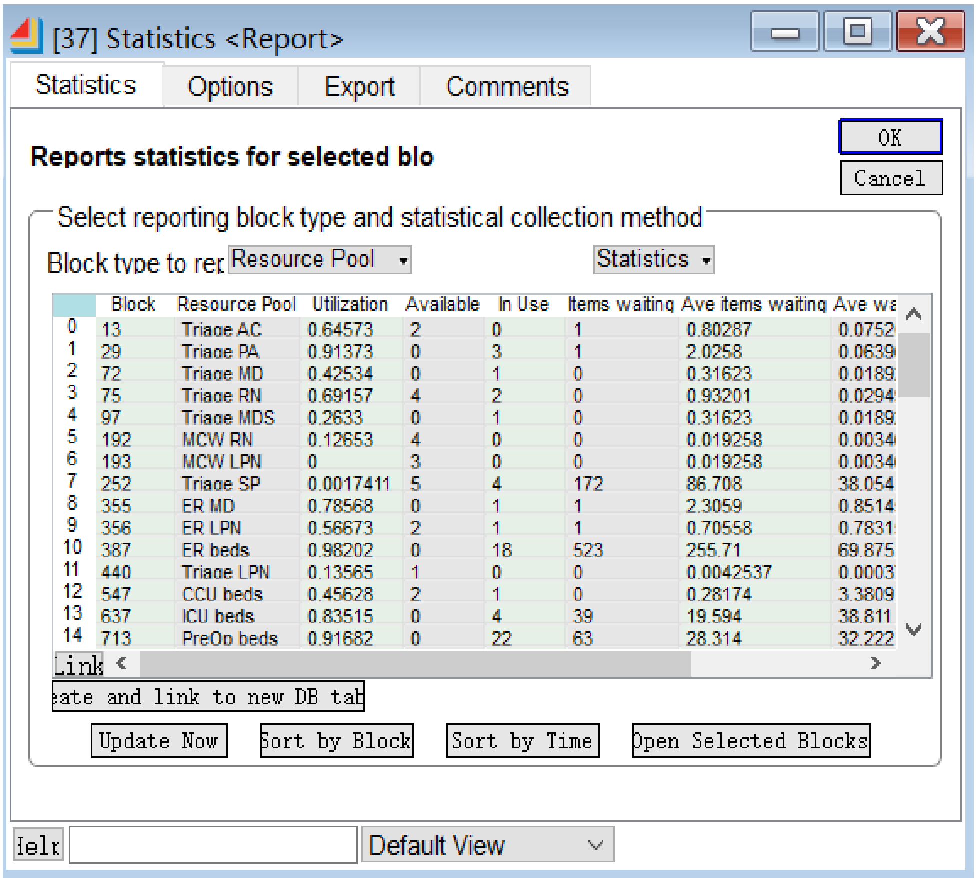


Figure 150: Data report

The number of resources is used as the X-axis, and the total number of waiting resources is used as the Y-axis. The relationship between the number of resources and the number of patients waiting for resources is plotted by plotter to determine whether the reduction of resources will affect the overall efficiency.

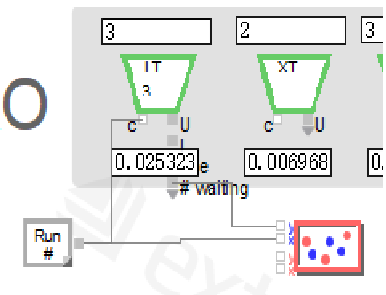
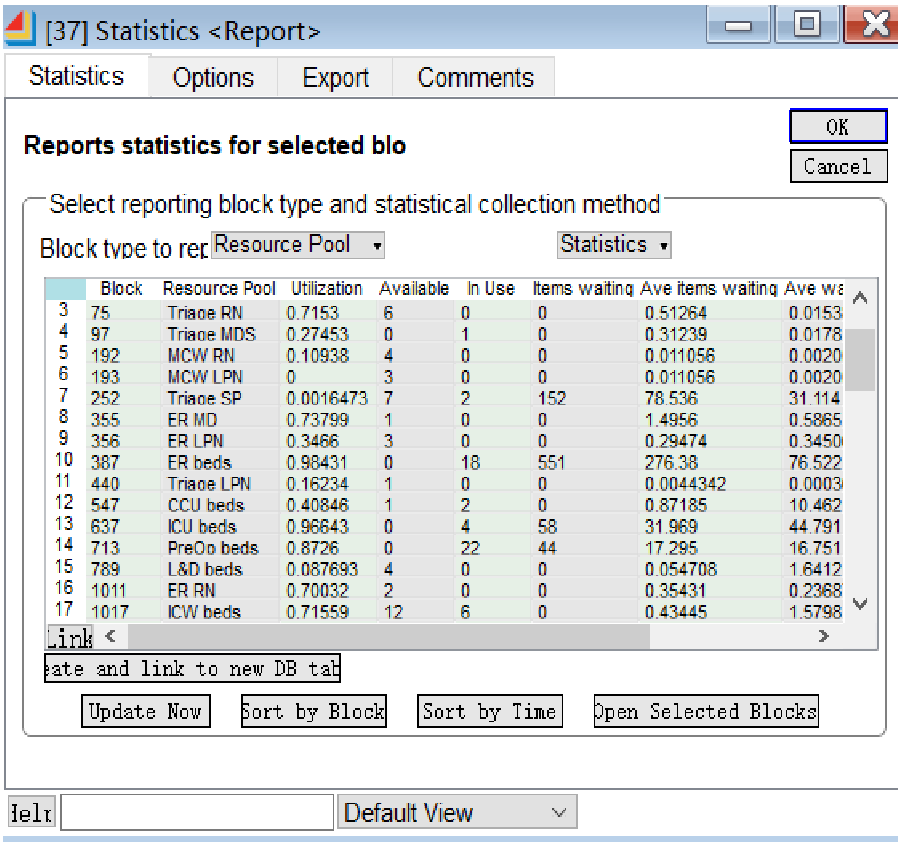


Figure 151: Resource diagram

First, the statistics show that there are redundant resources for LPN for MCW and ICW, RN for L&D, SP for LAB, and X-ray physicians and laboratory chemists



	Block	Resource Pool	Utilization	Available	In Use	Items waiting	Ave items waiting	Ave wa
3	75	Triage RN	0.7153	6	0	0	0.51264	0.0153
4	97	Triage MDS	0.27453	0	1	0	0.31239	0.0178
5	192	MCW RN	0.10938	4	0	0	0.011056	0.0020
6	193	MCW LPN	0	3	0	0	0.011056	0.0020
7	252	Triage SP	0.0016473	7	2	152	78.536	31.114
8	355	ER MD	0.73799	1	0	0	1.4956	0.5865
9	356	ER LPN	0.3466	3	0	0	0.29474	0.3450
10	387	ER beds	0.98431	0	18	551	276.38	76.522
11	440	Triage LPN	0.16234	1	0	0	0.0044342	0.0003
12	547	CCU beds	0.40846	1	2	0	0.87185	10.462
13	637	ICU beds	0.96643	0	4	58	31.969	44.791
14	713	PreOp beds	0.8726	0	22	44	17.295	16.751
15	789	L&D beds	0.087693	4	0	0	0.054708	1.6412
16	1011	ER RN	0.70032	2	0	0	0.35431	0.2368
17	1017	ICW beds	0.71559	12	6	0	0.43445	1.5798

Figure 152: Resource data

Optimizing the number of resources for these resources and plotting the number of people waiting for their counterparts shows that reducing the number of redundant resources to 1 does not have any impact on overall efficiency, as there is no patient waiting for it.

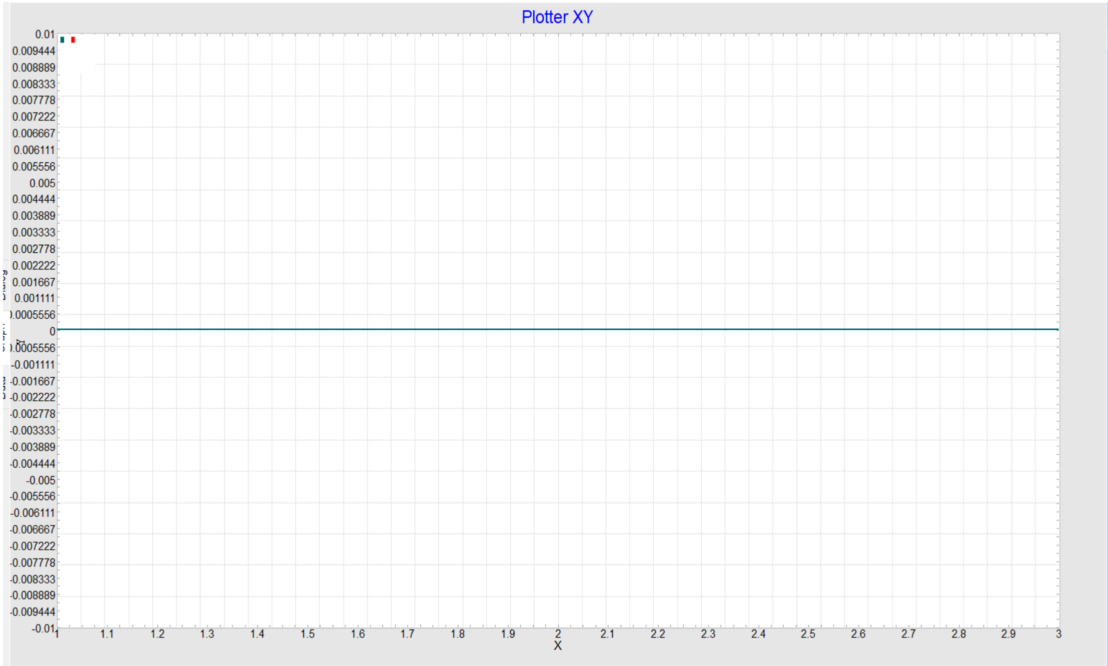


Figure 153: Diagram of the corresponding resource relationship

(3) Conclusion

MCW 和 ICW 的 LPN、L&D 的 RN、LAB 的 SP、以及 X 光医师和化验医师为冗余资源

The optimization results are as follows:

资源名称/前后变化	MCW LPN	ICW LPN	L&D RN	LAB SP	XT	LT	总数
优化前	3	2	2	4	3	2	16
优化后	1	1	1	1	1	1	6

Figure 154: Optimization results table

4.15 Question 5 of Phase 1

5. Choose metrics that you think represent the performance of your field hospital and evaluate them.

(1) Problem analysis

In order to minimize the error, the passing time of each tent should be counted separately and then added one by one, which can largely eliminate the influence of random factors and accurately reflect the degree of improvement of the current performance compared with the previous one

(2) Experimental design

The average passing time of each tent was summed and summed by the previous statistics, and the average of ten experiments was taken as the performance index of the current field hospital, and the shorter the total time, the higher the efficiency.

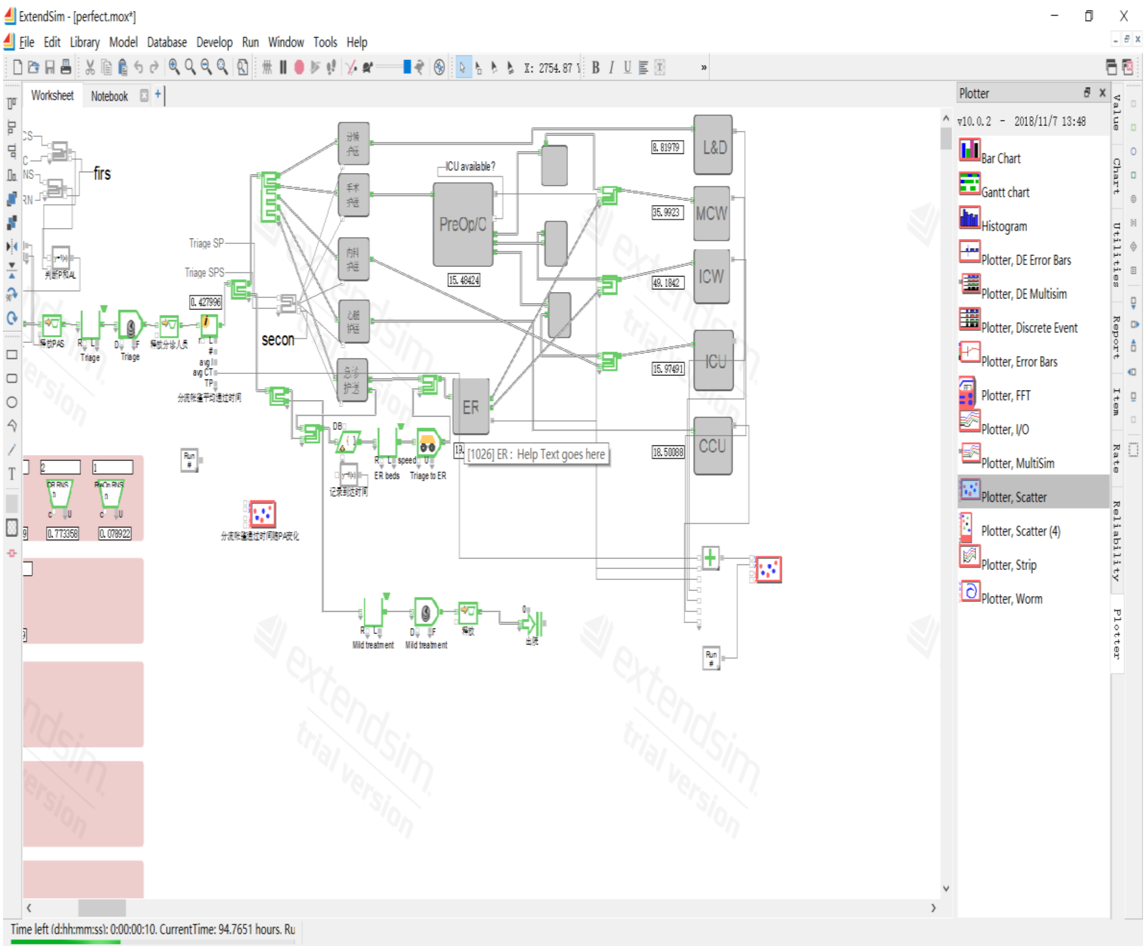


Figure 155: Average time through data

(3) Experimental execution

Taking 240 hours as the simulation time, ten experiments were carried out, and the average passing time range was between 234 and 278.6, and the average was 254.1594.

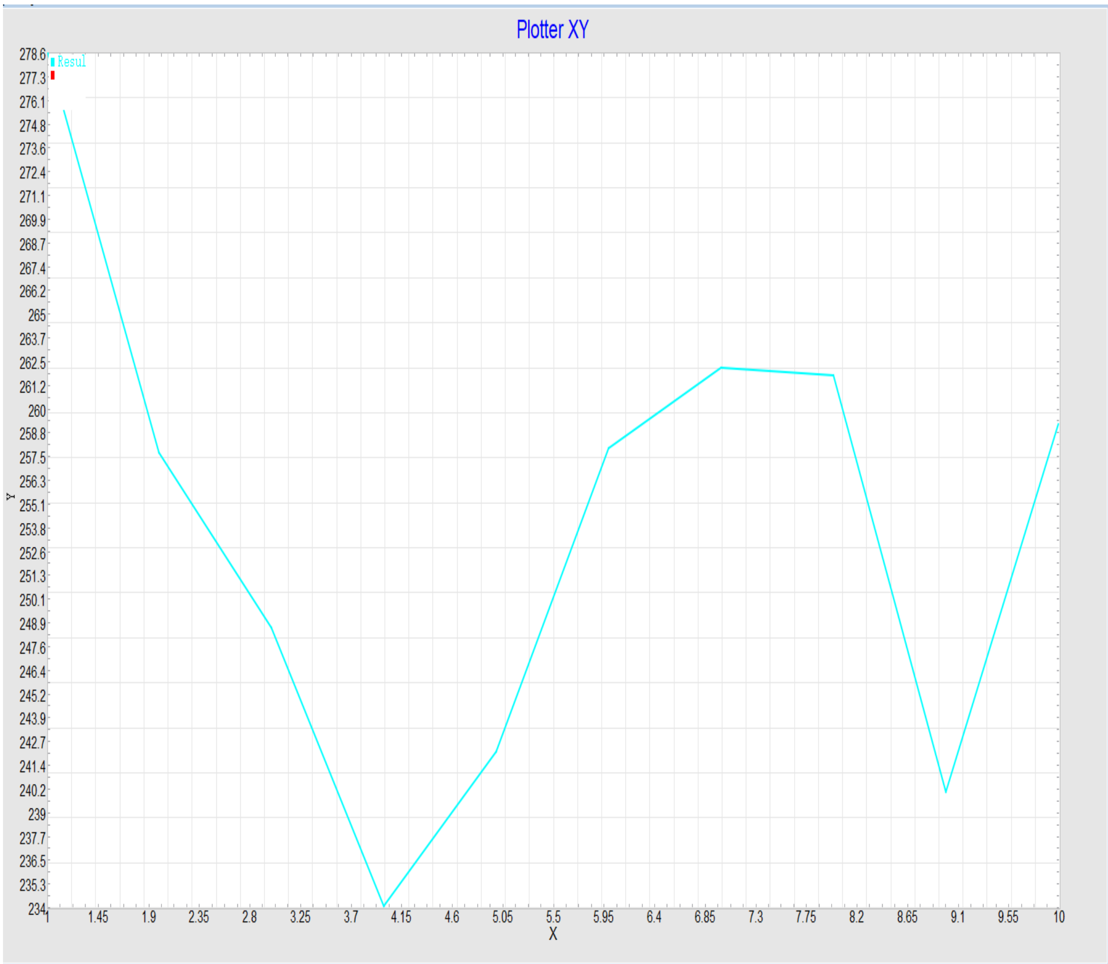


Figure 156: Plot of experimental execution results

(4) Conclusion

Although the average pass time is still very poor, the random influencing factors have been eliminated to a large extent, and it is the most suitable as an evaluation index for field hospitals.

4.16 Question 1 of Phase 2

1. How did your proposal improve the corresponding performance indicators (the indicators you chose in the first phase of evaluation) for the field hospital?

(1) Problem analysis

According to the requirements of the topic, two improvement plans for the field hospital model were formulated, and the improvement results were evaluated according to the performance indicators formulated above, and the better one was selected as the final optimization plan.

(2) Experimental design

After the redundant resources described above were removed, the surplus funds were used to make two programme improvements

Option 1: Recruit more staff to meet resource shortages

The bottleneck resources identified above are added to the number of personnel, and the number of additions is determined based on the optimal marginal benefit

Option 2: Improve efficiency by changing the layout of field hospitals and purchasing equipment

The SLP method was used to improve the layout of the original facility and new equipment was purchased

(3) Experimental execution

Option 1: Optimize the above resources and plot the average of the final 10 performance indicators

资源名称/前后变化	Triage SP	Triage PA	OR MD
优化前	8	4	2
优化后	18	6	6

Figure 157: Optimized averages

After 240 hours of simulation, a total of 10 simulations yielded a total average pass time that fluctuated between 268.1 and 220.2, with a mean value of 242.7117.

Figure 158: Simulation of experimental results

(4) Conclusion

The difference between scheme 2 and scheme 1 is similar, but the maximum and minimum values of the evaluation pass time of scheme 2 are much smaller than that of scheme 1, and the result of the final 10-times average is that scheme 2 is better, saving time by up to 26 hours and improving efficiency by about 10%.

时间（小时）/方案	方案一	方案二
优化前	254.1594	254.1594
优化后	242.7117	227.7949
优化成果	11.44774	26.36453

Figure 159: Optimization results

Option 2:

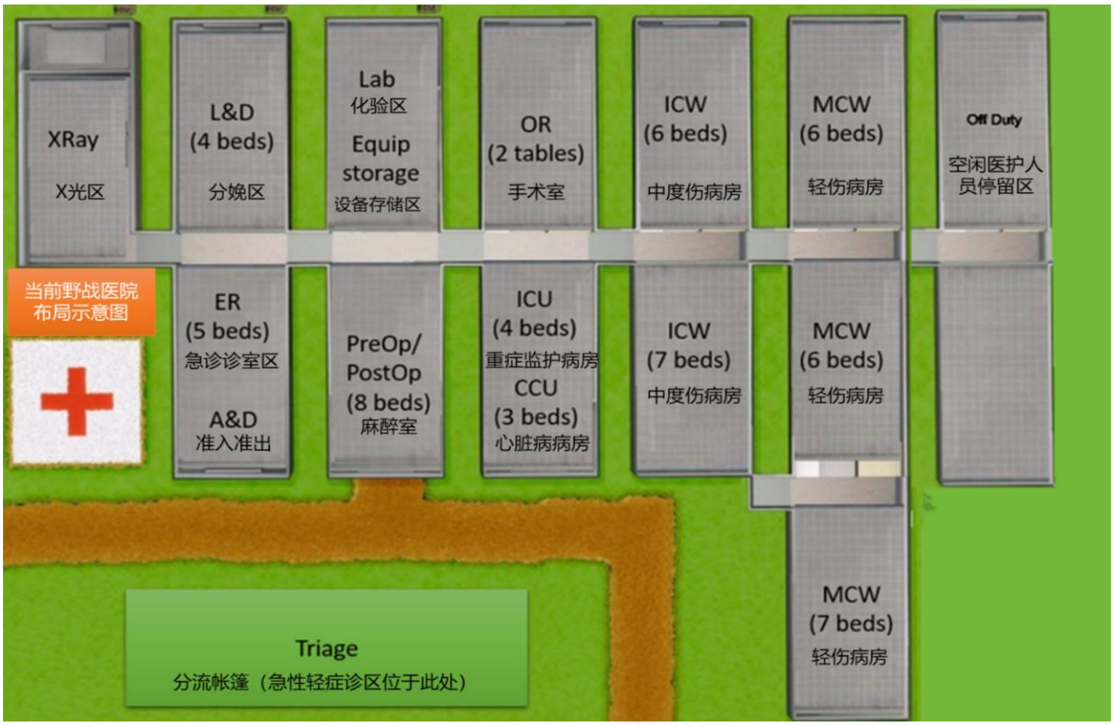


Figure 160: Optimized layout diagram

The results of optimizing the original layout according to the SLP method above are as shown in the figure above, and the newly purchased equipment is as follows

资源名称/前后变化	PreOp beds	ER beds	ICW beds
优化前	8	5	13
优化后	22	18	18

Figure 161: New equipment purchased

4.17 Question 2 of Phase 2

2. If other disasters occur in the future, such as earthquakes, will your improved field hospital provide adequate support for post-disaster medical care?

(1) Problem analysis

According to the data, the general natural earthquake disaster refers to the earthquake disaster that causes 50~300 deaths or major economic losses, and the direct economic loss of the earthquake does not exceed 1% of the province's GDP in the previous year; Earthquake disasters caused by earthquakes of magnitude 6.5~7.0 that occur in densely populated areas. According to the situation of the natural disaster, the probability of different diseases of patients in the model can be modified to simulate the results, and whether the post-disaster medical problems can be met can be specifically determined.

(2) Experimental design

Because the major disaster considered is an earthquake, the probability of the diversion in the original model was reversed, and the probability of minor injury was lowered from 0.9 to 0.1 in the Select Item, and the probability of severe injury was adjusted to 0.9, and the experiment was carried out according to the new model.

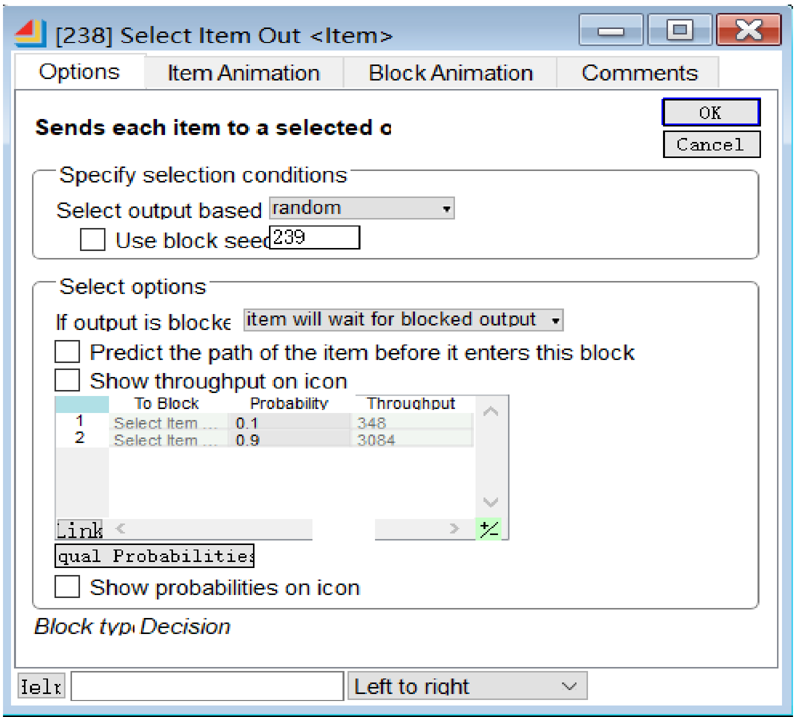


Figure 162: Shunt probability plot

(3) Experimental execution

After 240 hours of simulation, a total of 10 simulations resulted in a total average pass time that fluctuated between 415.4 and 358.4, with a mean value of 383.9569.

Figure 163: Plot of simulation results

(4) Conclusion

The current configuration of field hospitals is not sufficient to meet the occurrence of major disasters, and the average transit time of patients has increased by nearly 90%, mainly due to the severe shortage of beds in the CCU, which does not occur in daily visits without major disasters.

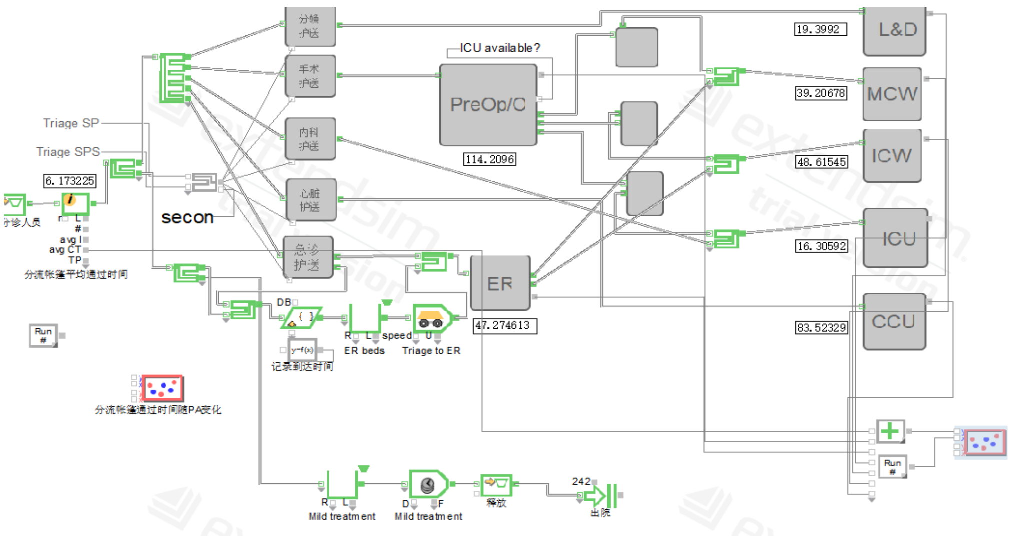


Figure 164: Schematic diagram of the model module

5 Conclusions and Recommendations

5.1 Summary of the work in this paper

In recent years, with the development of engineering technology and management level, the deployment of field hospitals has become more scientific and efficient. Based on the premise of reasonable assumptions and the provided data dictionary and related conditions, this paper uses some research methods in logistics engineering and industrial engineering, refers to some literatures, and uses Extendsim10 software to construct the field hospital model in combination with simulation technology. Finally, through the data given by the model, some effective results were analyzed, and a total of seven questions in the two stages were answered in detail. Here I summarize the research work of this design:

（1） Make reasonable assumptions based on pre-existing conditions and data dictionaries

The patient arrival data in the question was presented in the form of Excel, but in the end it was a question of which distribution to fit, so after a series of experimental tests of the data in the SPSS software, we determined the patient arrival data;

For the patient arrival method, we assume that the patient arrives on foot, which means that the patient is mobile, and in the modeling system, it is reflected in whether the patient needs to be escorted by a medical staff or can go to the office independently. Finally, our hypothesis was verified by experiments

In addition, for the distance of the specific layout and the rationality of some process sequences, we not only referred to the hospital model diagram on the Internet, but also observed in the Third Affiliated Hospital of Sun Yat-sen University in Guangzhou, and asked some doctors and nurses about their actual work processes to make final assumptions. In addition to this, we also make reasonable assumptions where some data from the model is unknown.

(2) Design a modeling approach based on existing data and assumptions

With some reasonable assumptions, we learned the basic operation of the Extendsim10 software online, and with the help of textbook-based research, we carried out the design of a series of research methods. For scheduling, we designed a 12-hour shift system based on hospital resources. For each question answer, we set the average pass time in the model and some chart reports to give data to answer specific questions. We also use some of our own unique methods in the design of some processes.

(3) Complete the whole model according to the modeling method

After designing the modeling method and making reasonable assumptions about some data, we used Extendsim10 software for modeling and simulation. First of all, we divided the workload according to the flow chart, each person made a large process module, and finally merged the resources and each module, and modified the problematic places, and in the continuous trial and modification, we finally completed the entire field hospital model.

(4) Answer specific questions based on the built model

After the whole field hospital model was built, we carried out corresponding experiments based on the problems at each stage, and after finding that the original model had some bottlenecks, we made some optimizations to the model. After we set the average pass time in the model and some chart reports to give the data, we discussed and analyzed whether it was effective, and after making sure that each question could be answered reasonably based on the data available, we came to the conclusion of each question.

5.2 Recommendations and Future Prospects

Due to the limitations of its own level and time, the research on some issues in this paper is not deep enough, and the following suggestions and prospects are put forward for the future research based on the conclusions obtained in this paper:

(1) This paper only constructs the hospital model of the modeling simulation system through the topic conditions and some assumptions, but it does not consider many problems in reality in depth, and lacks practicability.

(2) The design of some resources only refers to the data of the data dictionary, and does not take into account the intermediate rest time of each doctor and nurse, it is impossible for people to work all the time, if it is close to reality, each workflow should be added to each person's intermittent time, but the actual assumption is too difficult, so the time distribution fitting on the work is carried out according to the data of the data dictionary to each person's workflow.

(3) Under the current international situation and China's national conditions, the repeated problems of the new crown epidemic are more frequent and serious than some natural disasters, and we are a field hospital set up for disasters, if we can simulate the cabin hospital, it will be more practical and more in line with the actual needs, and there are currently Huoshenshan and Leishenshan and other cabin hospitals for reference, and the process and design of modeling and simulation will be closer to reality.

In addition, due to the limitations of the members' experience and analysis methods, the design of this model may not be perfect, and there is still a lot of work to be done in the design of the model in the future.

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