PROJECT 2 - MANUFACTURING SYSTEM

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1. DESIGN

enum EventType:

```
{ARRIVAL, DEPARTURE, BREAKDOWN, REPAIR, MAINTENANCE, SHIFT_CHANGE, RM_SUPPLY}
```

- **ARRIVAL:** Represents the beginning (arrival) of the event.
- **DEPARTURE:** Represents the end (departure) of the event.
- **BREAKDOWN:** Represents failure.
- **REPAIR:** Represents the repair event and the maintenance end event.
- **MAINTENANCE:** Represents maintenance event.
- **SHIFT_CHANGE:** Represents the time of shift change.
- **RM_SUPPLY:** Represents the time of raw material procurement.

Classes:

- **Event Class:** The class that represents information such as the time the event occurred, the event type, the machine ID, the stage name, and the product type.
- **Machine Class:** The class that holds the machine properties such as machine ID, machining time, failure rate, repair time, etc.
- **Operator Class:** The class that monitors the compliance of the operator ID and shift pattern.
- **ProductionStage Class:** The class that contains the name of the production stage, the list of machines, and the list of operators. Assigns machine/operator to vectors where machines or operators on the current stage are kept. It also includes functions to check whether the machines are operational and select the appropriate machine. While checking the operationality of the machine, the machines taken into maintenance are returned to their previous failure rates, because if maintenance is not performed again, the falling failure rates must increase.
- **Simulation Class:** The main class that manages the production simulation. It contains the priority event queue, stage map and simulation parameters.

- **Simulation Parameters:**

  int machinecount1: Determines the number of machines in all stages (as well as the number of operators).
  double current_time: Keeps the time at which the event occurred.
  double shift_duration: Calculates how many hours there will be a shift change in a day.
  int num_shifts: Number of shift changes per day.
  int finished_products_P1: Number of Type 1 products produced.
  int finished_products_P2: Number of Type 2 products produced.
  int end_time: End time of the simulation
  int raw_materials_T1: Number of Type 1 products in raw material.
  int raw_materials_T2: Number of Type 2 products in raw material.
  int rm_supply_time1: Time of raw material supply of Type 1 product.
  int rm_supply_time2: Time of raw material supply of Type 2 product.
  int lack_of_rm1: How many times there is insufficient raw material for a Type 1 product.
  int lack_of_rm2: How many times there is insufficient raw material for a Type 2 product.
  int maintenance_interval1: Maintenance time for Type 1 product machines.
  int maintenance_interval2: Maintenance time for Type 2 product machines.

2. IMPLEMANTATION DETAILS

Initial Settings and Adding Stages:

- The `initialize()` method creates the machines and operators for each stage. Different machine features are added for each product type and add the stages to the simulation object with the `add_stage()` method.
- The `schedule_raw_materials_type1()` method plans the raw material supply event for the type 1 product until the end of the simulation.
- The `schedule_raw_materials_type2()` method plans the raw material supply event for the type 2 product until the end of the simulation.
- The `schedule_maintenance()` method plans the machine maintenance event until the end time of the simulation, according to the maintenance times of different types of products.
- The `schedule_shift_changes()` method assigns the operators to the shifts in sequence on each stage and plans the shift change time event.

Event Scheduling:

- The `schedule_event()` method adds events such as arrival, departure, breakdown, repair, shift change that will occur at a certain time to the priority event queue. It is used to plan events.

Running the Simulation:

- The `run()` method retrieves events from the event queue and ensures that each event is handled appropriately. In the simulation, an operator was assigned for each machine. Depending on the shift status of these operators, the machines were either used or rendered unusable. Additionally, each machine was set to process one product at a time.

  The processing of events is carried out in `handle_*` methods:

  - In the `handle_arrival` method, after the current shift is found, the operability of the operators and the functionality of the machines are checked according to this shift and a suitable machine is found. By making checks in accordance with the stage, the product is processed (planned for departure) or arrival is planned for product entry again until the conditions are met.
  - In the `handle_departure` method, the end of the product being processed takes place and the event is planned for the next stage. If the product is in the final stage, the number of finished products is increased. The fault status of the machine is checked. If it has failed, the event is planned for the failure. Also if there is an empty machine at the initial stage, planning is carried out for the processing of new products.
  - In the `handle_breakdown` method, it is ensured that the faulty machine remains inoperable during the repair period and the repair is planned to be completed.
  - In the `handle_repair` method, the repair period of the machine ends and the machine becomes operational again.
  - In the `handle_maintenance` method, the machine is taken into maintenance and repair is planned for its completion (the machine is made operational). In addition, the failure rate is reduced by 50% because maintenance is carried out. In addition, while checking operational machines, machines that have passed some time from the last maintenance time are also reverted to the previous failure time.
  - In the `handle_shift_change` method, the current shift is calculated and the operators working at that time are rendered inoperable at the next shift, and vice versa.
  - In addition, when the raw material supply time comes, that is, in the RW_SUPPLY case, a certain amount of unit raw material is added for products 1 and 2.

- With the `suggest_improvements` method, the results are analyzed and suggestions are listed.

3. FINDINGS AND RECOMMENDADITONS

Performance criteria of each stage in the production process were obtained and the products waiting in the production stages, failures, repair times and production quantities were recorded:

Case 1

Enter number of machines: 5

Enter number of shifts per day: 3

Finished products of product type 1: 2258

Finished products of product type 2: 2528

Lack of Raw Materials of product type 1: 0

Lack of Raw Materials of product type 2: 0

Recommendations:

Shift 3 in Stage Quality Control (Product Type 1): 8 units of idle time.

Suggestion: Optimize shift schedules to ensure operators are available when needed, reducing idle time for machines.

3. Stage Optimization for Stage Quality Control:

Machines in this stage have a maximum waiting time of 7 units.

3. Stage Optimization for Stage Packaging:

Machines in this stage have a maximum waiting time of 5.5 units.

3. Stage Optimization for Stage Assembly:

Machines in this stage have a maximum waiting time of 8 units.

3. Stage Optimization for Stage Machining:

Machines in this stage have a maximum waiting time of 10 units.

3. Stage Optimization for Stage Raw Material Handling:

Machines in this stage have a maximum waiting time of 6 units.

Suggestion: Analyze stages with high waiting times or low throughput and identify potential improvements, such as adding more machines or optimizing machine assignment logic.

4. Breakdowns for Stage Quality Control:

Machines in this stage had 511 breakdowns.

4. Breakdowns for Stage Packaging:

Machines in this stage had 34 breakdowns.

4. Breakdowns for Stage Assembly:

Machines in this stage had 117 breakdowns.

4. Breakdowns for Stage Machining:

Machines in this stage had 67 breakdowns.

4. Breakdowns for Stage Raw Material Handling:

Machines in this stage had 78 breakdowns.

Suggestion: Reduce the maintenance interval of machines to prevent malfunctions.

Case 2

Enter number of machines: 3

Enter number of shifts per day: 3

Finished products of product type 1: 1311

Finished products of product type 2: 1465

Lack of Raw Materials of product type 1: 0

Lack of Raw Materials of product type 2: 0

Recommendations:

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3. Stage Optimization for Stage Quality Control:

Machines in this stage have a maximum waiting time of 7.03688e+14 units.

3. Stage Optimization for Stage Packaging:

Machines in this stage have a maximum waiting time of 5.5 units.

3. Stage Optimization for Stage Assembly:
Machines in this stage have a maximum waiting time of 8 units.
3. Stage Optimization for Stage Machining:
Machines in this stage have a maximum waiting time of 10 units.
3. Stage Optimization for Stage Raw Material Handling:
Machines in this stage have a maximum waiting time of 6 units.
Suggestion: Analyze stages with high waiting times or low throughput and identify potential improvements, such as adding more machines or optimizing machine assignment logic.
4. Breakdowns for Stage Quality Control:
Machines in this stage had 25 breakdowns.
4. Breakdowns for Stage Packaging:
Machines in this stage had 18 breakdowns.
4. Breakdowns for Stage Assembly:
Machines in this stage had 72 breakdowns.
4. Breakdowns for Stage Machining:
Machines in this stage had 53 breakdowns.
4. Breakdowns for Stage Raw Material Handling:
Machines in this stage had 43 breakdowns.
Suggestion: Reduce the maintenance interval of machines to prevent malfunctions.

Case 3

Enter number of machines: 7
Enter number of shifts per day: 2

Finished products of product type 1: 3873
Finished products of product type 2: 2928
Lack of Raw Materials of product type 1: 59948
Lack of Raw Materials of product type 2: 50825

Recommendations:

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1. Raw Material Supply Adjustment:

Raw material shortage incidents occurred 59948 times for Product Type 1.

Suggestion: Increase the frequency or quantity of raw material supplies of product 1 to minimize delays due to resource shortages or reduce the machine count.

Raw material shortage incidents occurred 50825 times for Product Type 2.

Suggestion: Increase the frequency or quantity of raw material supplies of product 2 to minimize delays due to resource shortages or reduce the machine count.

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3. Stage Optimization for Stage Quality Control:

Machines in this stage have a maximum waiting time of 7 units.

3. Stage Optimization for Stage Packaging:

Machines in this stage have a maximum waiting time of 5.5 units.

3. Stage Optimization for Stage Assembly:

Machines in this stage have a maximum waiting time of 8 units.

3. Stage Optimization for Stage Machining:

Machines in this stage have a maximum waiting time of 10 units.

3. Stage Optimization for Stage Raw Material Handling:

Machines in this stage have a maximum waiting time of 6 units.

Suggestion: Analyze stages with high waiting times or low throughput and identify potential improvements, such as adding more machines or optimizing machine assignment logic.

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4. Breakdowns for Stage Quality Control:

Machines in this stage had 69 breakdowns.

4. Breakdowns for Stage Packaging:

Machines in this stage had 46 breakdowns.

4. Breakdowns for Stage Assembly:

Machines in this stage had 118 breakdowns.

4. Breakdowns for Stage Machining:

Machines in this stage had 92 breakdowns.

4. Breakdowns for Stage Raw Material Handling:

Machines in this stage had 96 breakdowns.

Suggestion: Reduce the maintenance interval of machines to prevent malfunctions.