Project Title

Intelligent Management of Automated Guided Vehicles (AGVs) for ad-hoc Surgical Instrument Conveyance

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Organisation(s) Involved

SingHealth, National University of Singapore, Singapore General Hospital

Healthcare Family Group(s) Involved in this Project

Healthcare Administration

Applicable Specialty or Discipline

Operating Theatre, Facilities Engineering

Aim(s)

The objective of this project is to find the optimal AGV docking location and optimal scenario: number of AGVs and AGV restocking frequency based on three criterias:

1) AGVs utilisation rate*

- How often AGVs are used to serve the ad-hoc requests

2) Cost per AGV fulfilment*

- Total cost of AGVs / Total number of ad-hoc request fulflled by AGVs

3) Breakeven period*

Time taken for the monetary benefits from AGVs to surpass the cost of AGVs

Background

See poster appended/ below

Methods

See poster appended/ below

Results

See poster appended/ below

Conclusion

See poster appended/ below

Additional Information

Singapore Healthcare Management (SHM) Congress 2022 – 2nd Prize (Supply Chain Management category)

Project Category

Care & Process Redesign

Value Based Care, Productivity, Manhour Saving, Operational Managmeent

Keywords

Automated Guided Vehicles

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Intelligent Management of Automated Guided Vehicles (AGVs) for ad-hoc Surgical Instrument Conveyance

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Background & Introduction

Operating Theatre (OT) Circulating Nurses are highly trained manpower that is critical part of surgical teams. However, they can spend up to 20% of their time searching and fetching sterile surgical instruments from and around the OTs.

These highly trained and specialized nurses may have their manpower wasted on these repetitive manual tasks and a solution is needed to reduce the inefficiency. The use of Automated Guided Vehicles (AGV) is recommended in reducing this manpower wastage.

Aim

The objective of this project is to find the optimal AGV docking location and optimal scenario: number of AGVs and AGV restocking frequency based on three criterias:

1) AGVs utilisation rate*
   - How often AGVs are used to serve the ad-hoc requests
2) Cost per AGV fulfilment*
   - Total cost of AGVs / Total number of ad-hoc request fulfilled by AGVs
3) Breakeven period*
   Time taken for the monetary benefits from AGVs to surpass the cost of AGVs

Workflow

Simulation Model Construction
- Gathering Data
- Model Construction (Logic & Path Mover System that simulates actual layout)

Model Output Analysis (Part 1: Optimal restocking frequency & No. of AGVs)
- Obtain utilization rate of AGV in fulfilling requests for 40 over scenarios.
- Three Criteria to determine optimal solution:
- 1. At least 90% AGV utilization rate
- 2. Lowest cost per AGV fulfilment
- 3. Shortest breakeven period.

Model Output Analysis (Part2: Optimal docking location)
- Analyse average travelling time of AGV
- Docking locations: Top right, bottom right, top left, bottom left

Methodology

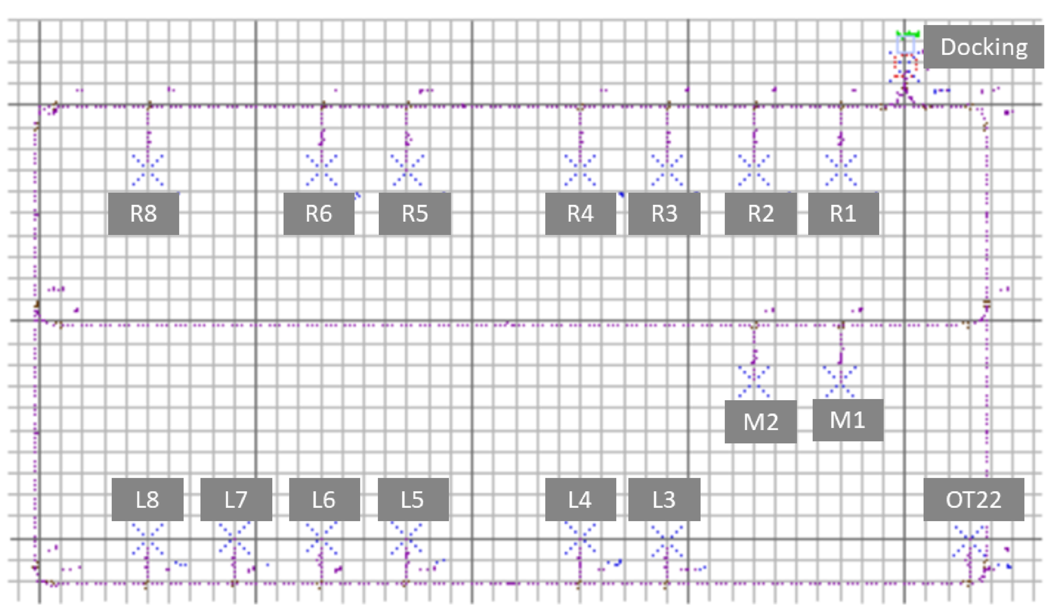
- Step 1: Using relevant data such as OT layout and frequencies for each ad-hoc instrument type requested by each theatre, the simulation model was constructed. The number of yearly ad-hoc request is estimated to be 23,003 requests (assuming that daily request frequency follows normal distribution with mean and standard deviation of 36 and 5 minutes)
- Step 2: The developed model deployed to simulate 40 different scenarios (2-5 no. of AGVs & 1-10 times per day restocking frequency) and obtained AGV utilisation rate for each case. Lifecycle cost analysis of AGVs was carried out to compute the cost per AGV fulfilment and AGVs cost breakeven period as well.
- Step 3: The optimal solution was found based on the three criteria
  1) At least 90% AGV utilisation rate.
  2) Lowest cost per AGV fulfilment.
  3) Shortest breakeven period.
- Step 4: Using the best scenario, the model was fitted with four different docking locations (Top right, bottom right, top left, bottom left). The optimal location is identified by shortest average travelling time of AGVs.

Results

Frequency	Number of AGVs	Number of request fulfilled by AGV	Number of request fulfilled by Nurse	Cost of AGV	Utilisation Rate	Cost of request fulfilled by AGV	Breakeven Period
10	4	23003	0	135568	100.00%	5.89	3.64
9	5	23003	0	169460	100.00%	7.37	4.55
10	5	23003	0	169460	100.00%	7.37	4.56
8	5	22991	12	169460	99.95%	7.37	4.54
9	4	22991	12	135568	99.95%	5.90	3.64
6	5	22979	24	169460	99.90%	7.37	4.53
8	4	22967	36	135568	99.84%	5.90	3.64
7	5	22967	36	169460	99.84%	7.38	4.54
5	5	22943	60	169460	99.74%	7.39	4.52
7	4	22930	73	135568	99.68%	5.91	3.63
10	3	22919	84	101676	99.63%	4.44	2.74
6	4	22870	133	135568	99.42%	5.93	3.64
9	3	22835	168	101676	99.27%	4.45	2.75
4	5	22751	252	169460	98.90%	7.45	4.55
8	3	22679	324	101676	98.59%	4.48	2.76
5	4	22585	418	135568	98.18%	6.00	3.68
7	3	22357	646	101676	97.19%	4.55	2.8
3	5	22093	910	169460	96.04%	7.67	4.68
4	4	21996	1007	135568	95.62%	6.16	3.77
6	3	21977	1026	101676	95.54%	4.63	2.84
10	2	21648	1355	67784	94.11%	3.13	1.94
9	2	21168	1835	67784	92.02%	3.20	1.98
5	3	21090	1913	101676	91.68%	4.82	2.95

The scenario of 2 AGVs & 10 times per day restocking frequency (highlighted in yellow) is the optimal solution. It has the utilisation rate of 94.1%, the lowest cost per AGV fulfilment and shortest breakeven period.

For docking location, the optimal location is top right which is also the current location.



Conclusion

With the simulation model, different scenarios were considered to find optimal solution. Using the three criteria, the optimal number of AGVs and restocking frequency is 2 and 10 times per day respectively. The optimal docking location should be at the top right of the OT floor plan.

The relationship of AGV utilization rate against restocking frequency and number of AGVs can be described by the following equation:
Utilisation Rate = 10.88 + 58.16lg(AGV) + 64.28lg(freq),
which can give a prediction of adjusted AGV number or restocking frequency if in future there is any change in AGV or manpower arrangement.