Simulation-based Heavy Equipment Planning for Building Mass Rescue Operation

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Abstract

The success of mass rescue operations, such as in the aftermath of a building collapse, requires effective use of limited resources to search for more people on time constraints and expedite the debris removal process. However, the two major processes of the rescue operation, debris removal and survival search, have different objectives (i.e., removal of debris and search for survivors, respectively) but share resources, such as excavators and trucks, thereby making resource planning for mass rescue operations challenging. We propose a novel approach to optimize heavy equipment planning for mass rescue operations through discrete event simulation (DES). Debris collection and survivor search operations are simulated as two distinctive processes that share the input of excavators and trucks. One key challenge in developing a simulation model of the rescue operation is the lack of productivity data for each process. To overcome this issue, small-scale experiments were conducted in which students operate 1:14 scale heavy equipment for debris removal and rescue operations, while their productivity for each operation is recorded. The measured productivity data from the small-scale experiments are used in the developed simulation model in order to identify bottleneck resources within these two processes. The use of equipment is planned in a way that addresses such resource bottlenecks and thus expedites the overall mass rescue operation. Our findings have important implications for enhancing the efficiency and effectiveness of rescue operations in the aftermath of a disaster.

Methods

1. Using the small-scale simulation (in Fig. 1), measure productivity data for the rescue operation and use them as input for the subsequent computer simulation (the DES model).
2. Create an activity cycle diagram using DES software that models this process and then input the range of the times recorded (Fig. 2).
3. Run the simulation on the software and analyze the efficiency of each process in the cycle (Fig. 3)

Results

Fig. 1 Simulating rescue operations using small-scale heavy equipment

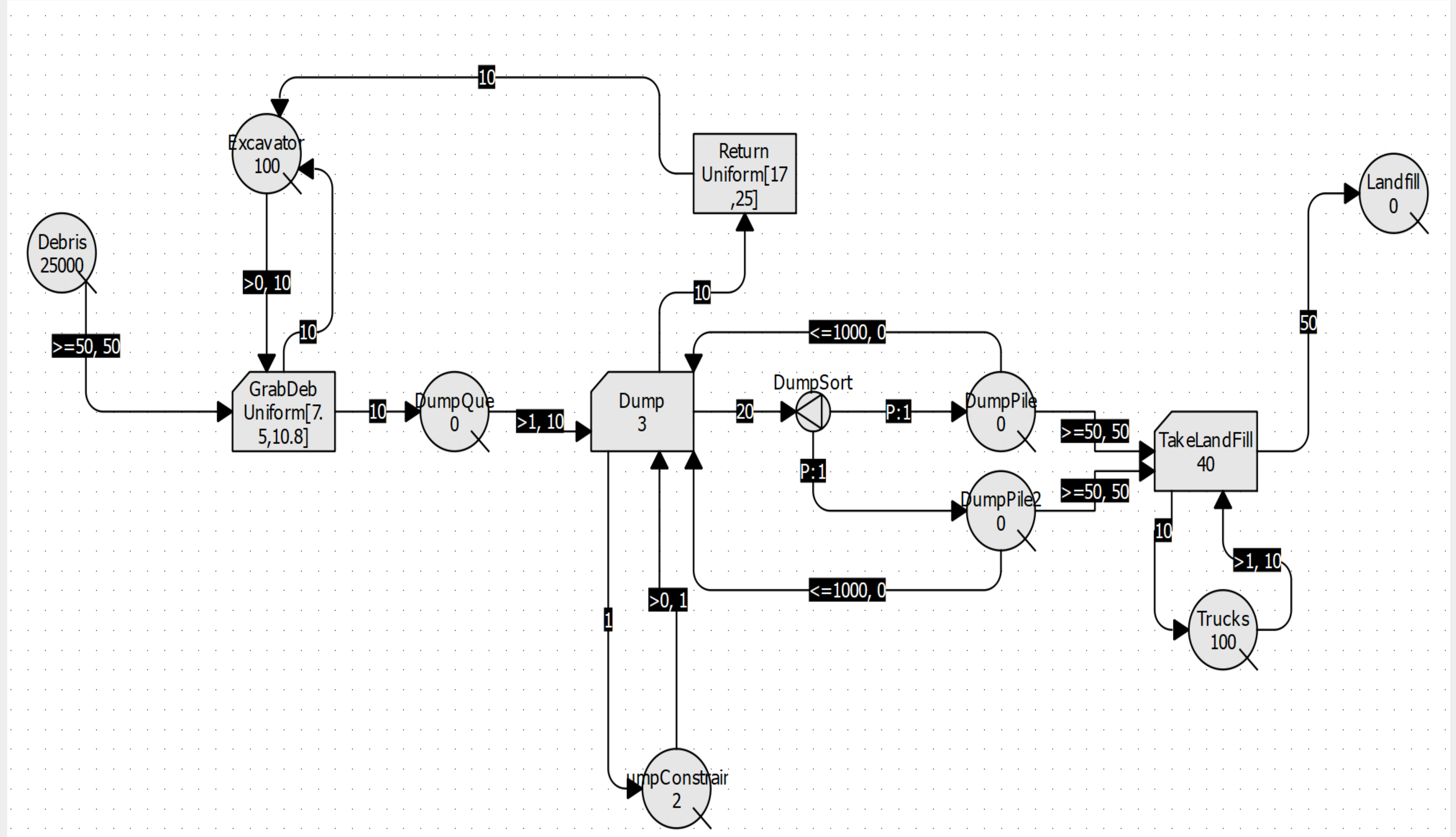

Fig. 2 Activity cycle diagram using DES software

	Queue Name	Resource Type	Current Count	Total Count	**Average Wait**	Average Content	Minimum Content	Maximum Content
1	Debris	res	22850.00	25000.00	30.52	23874.83	0.00	25000.00
2	DumpCo...	res	0.00	18.00	0.85	0.48	0.00	2.00
3	DumpPile	res	20.00	120.00	4.90	18.41	0.00	60.00
4	DumpPile2	res	100.00	200.00	10.82	67.70	0.00	160.00
5	DumpQue	res	120.00	300.00	5.70	53.45	0.00	140.00
6	Excavator	res	10.00	430.00	0.00	0.00	0.00	100.00

	Activity Name	Total Instances	Current Instances	First Start	Last Start	First Finish	Last Finish	Average Duration	Std.Dev. Duration	Minimum Duration	Maximum Duration	Average Interval	Std. Dev. Interval	Minimum Interval	Maximumn Interval
1	Dump	18	2	7.53	31.73	10.53	34.73	3.00	0.00	3.00	3.00	1.42	1.81	0.19	2.81
2	GrabDeb	42	12	0.00	30.72	7.53	40.35	9.36	0.85	7.53	10.77	0.75	3.30	0.00	7.53
3	Return	16	13	10.53	31.73	29.29	54.70	20.79	3.83	17.19	23.33	1.41	1.82	0.19	2.81
4	TakeLand...	2	2	25.53	31.53	65.53	71.53	40.00	0.00	40.00	40.00	6.00	nan	6.00	6.00

Fig. 3 Efficiency results with average wait time highlighted

Conclusion

The activity cycle diagram (ACD) in Fig. 2 demonstrates the proposed optimization model that focuses on both debris removal and search and rescue operations. After running the simulation, the efficiency results were presented as seen in Fig. 3, with the average wait time for each subprocess highlighted. These wait times demonstrate the efficiency of the debris removal process, as each time fell below 11 minutes, averaging closer to 4 minutes and 45 seconds. However, the grand average for the search and rescue operation was approximately 30 minutes and 52 seconds, which indicates that the resource allocation in the ACD wasn't completely optimized, although still relatively efficient. Therefore, this project is still in process, as the model that satisfies both the debris removal and the search and rescue operation still needs development. In future modifications of this project, the ACD should be modified to accommodate for the bottleneck resources and constraints that slow this process down.

References

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