28 A Performance Calculator for Shuttle-based Storage and Retrieval System Design

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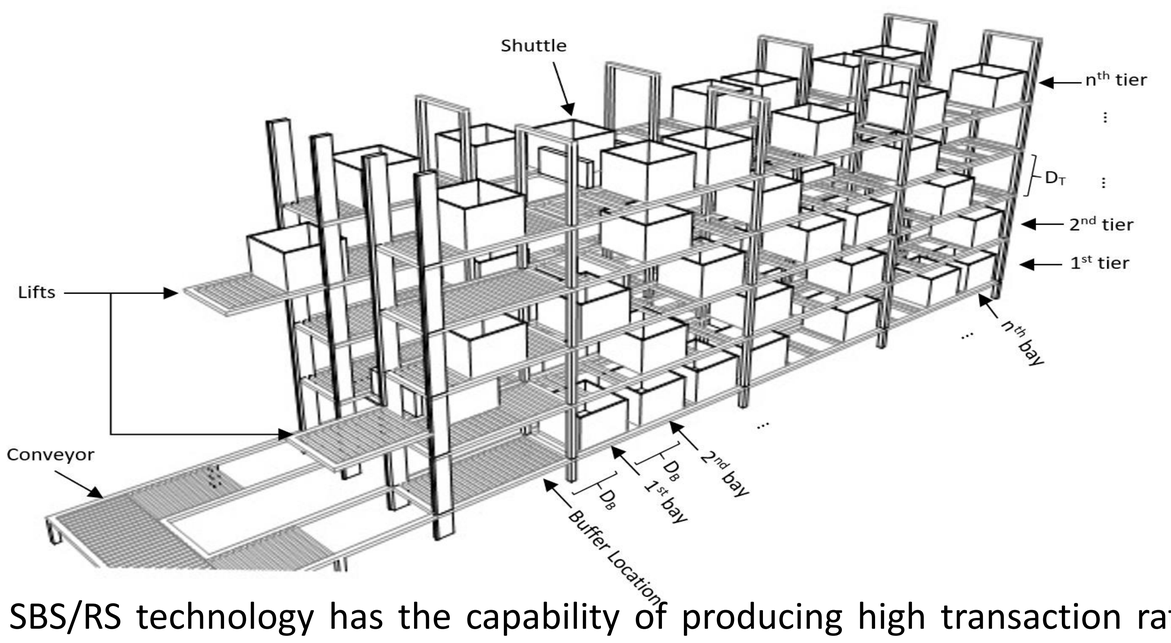
OBJECTIVE

In this study, we present an analytical model based tool that can estimate critical performance measures from a pre-defined shuttle-based storage and retrieval system (SBS/RS) design.

BACKGROUND

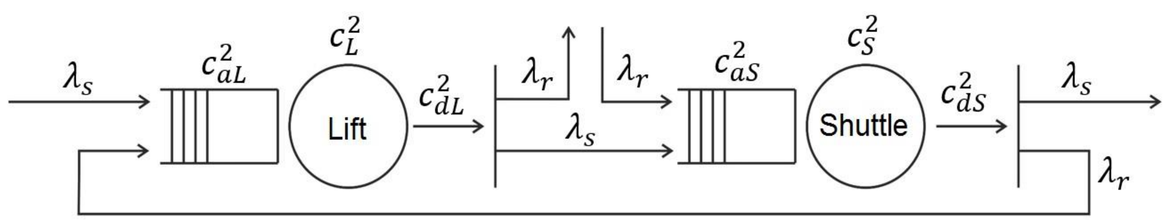


SBS/RS technology has the capability of producing high transaction rates due to comprising multiple tiers of storage with dedicated shuttles for each level – tier-captive shuttles. SBS/RS is developed as an alternative system to the "traditional" mini-load AS/RS crane that may be inadequate for the transaction rates needed over a given number of storage locations.

METHODOLOGY

QUEUING NETWORK MODELLING APPROACH

In the OQN model of an SBS/RS, storage and retrieval transactions are assumed to be arriving customers and, the lifts and the shuttles are two different types of servers. An arriving transaction (storage or retrieval) enters the network of servers immediately. λ_S shows the mean arrival rate of the storage transactions and λ_R shows the mean arrival rate of the retrieval transactions in the system. Nodes represent the servers (i.e., lifts and shuttles).



- mean waiting time in lift queue, $E(WQ_L)$,
- mean number of transactions waiting in lift queue, $E(LQ_L)$,
- mean utilization of lift (ρ),
- mean travel time per transaction - $E(T_L)$ and $E(T_S)$,
- energy consumption per transaction - $E(W_L)$ and $E(W_S)$,
- energy regeneration amount per transaction - $E(RW_L)$ and $E(RW_S)$,

$$\frac{\left|E(WQ_L)_{\text{Analytical}} - E(WQ_L)_{\text{Simulation}}\right|}{E(WQ_L)_{\text{Simlation}}} \times 100$$

RESULTS

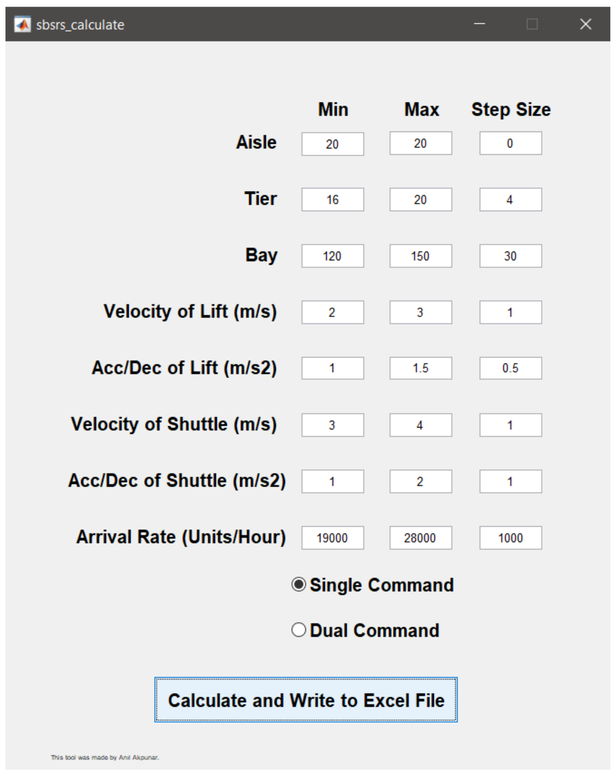
TRAVEL TIME, ENERGY CONSUMPTION AND ENERGY REGENERATION RESULTS

Analytical Results					
$E(T_L)$ (min.)	$E(T_S)$ (min.)	$E(W_L)$ (kWh)	$E(W_S)$ (kWh)	$E(RW_L)$ (kWh)	$E(RW_S)$ (kWh)
5.03	26.11	$2.07 \cdot 10^{-3}$	$6.16 \cdot 10^{-4}$	$2.5 \cdot 10^{-4}$	$1.11 \cdot 10^{-4}$
Simulation Results					
5.03 ±0.0206	26.11 ±0.02	$2.07 \cdot 10^{-3}$	$6.16 \cdot 10^{-4}$	$2.5 \cdot 10^{-4}$	$1.11 \cdot 10^{-4}$

UTILIZATION AND QUEUING PERFORMANCE RESULTS

		Analytical Results			Simulation Results			APE (%)
Ex.	$\lambda_S + \lambda_R$	ρ_L	$E(WQ_L)$	$E(LQ_L)$	ρ_L	$E(WQ_L)$	$E(LQ_L)$	
1	26,000	0.907	14.32	5.17	0.906	13.73	4.95	4.26
2	25,000	0.873	9.80	3.40	0.872	9.5	3.30	3.05
3	24,000	0.838	7.23	2.41	0.837	7.04	2.34	2.72
4	23,000	0.803	5.58	1.78	0.802	5.48	1.75	1.70
5	22,000	0.768	4.42	1.35	0.767	4.37	1.33	1.25
6	21,000	0.733	3.58	1.04	0.732	3.54	1.03	0.89

CONCLUSION



In this work, we develop a tool based on an OQN analytical model, estimating some critical performance measures from a pre-defined SBS/RS design. After validating the tool by using simulation results, we can suggest the utilization of this tool for the practitioners for deciding the right design of an SBS/RS. Specifically, by the developed tool, one can evaluate numerous SBS/RS designs promptly and decide on the right SBS/RS design for his/her requirements.

ACKNOWLEDGMENT

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