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A system dynamics approach to maintenance capacity optimization under split acquisition: A military case study

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A B S T R A C T

This study examines maintenance capacity adjustment strategies under split acquisition, a common practice in defense procurement driven by budgetary and production constraints. Using the Republic of Korea Air Force (ROKAF) F-35A as a case, the study investigates how time gaps between acquisition phases, combined with bathtub-shaped failure patterns, generate non-linear shocks in maintenance workload that threaten operational availability. A System Dynamics (SD) model is developed to simulate a 40:20 split acquisition scenario and to compare three capacity adjustment strategies: Level (fixed), Chase (reactive), and Lead (proactive). The strategies are evaluated under review intervals of 3, 5, and 10 years to reflect realistic defense planning environments. The simulation results show that the reactive Chase strategy consistently fails to achieve the availability target of 75 % due to workforce training delays. In contrast, the proactive Lead strategy successfully defends availability by anticipating future workload changes. A 3-year review interval achieves the highest cost-effectiveness, while a 5-year interval, aligned with the Mid-term Defense Plan cycle, is identified as a realistic threshold for sustaining availability. However, under a 10-year review interval, even proactive strategies lose effectiveness. The findings highlight the importance of proactive, forecast-based decision-making and suggest that synchronizing maintenance review cycles with acquisition schedules within a 5-year horizon is essential for robust maintenance policy design.

A R T I C L E I N F O

Keywords:
Simulation;
System dynamics;
Operational availability;
Maintenance capacity planning;
Bathtub curve;
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References

[1] Ebeling, C.E. (2019). *An introduction to reliability and maintainability engineering*, 3rd edition, Waveland Press, Long Grove, USA.

[2] Nowlan, F.S., Heap, H.F. (1978). *Reliability-centered maintenance*, Report No. AD-A066579, United Airlines, San Francisco, USA.

[3] Choi, J., Moon, S. (2022). Rare event simulation by combining trend and probability: An application to naval ship critical failures, *Industrial Engineering & Management Systems*, Vol. 21, No. 1, 128-136, doi: 10.7232/iems.2022.21.1.128.

[4] De Pater, I., Reijns, A., Mitici, M. (2022). Alarm-based predictive maintenance scheduling for aircraft engines with imperfect Remaining Useful Life prognostics, *Reliability Engineering & System Safety*, Vol. 221, Article No. 108341, doi: 10.1016/j.ress.2022.108341.

[5] Jin, H., Song, X., Xia, H. (2023). Optimal maintenance strategy for large-scale production systems under maintenance time uncertainty, *Reliability Engineering & System Safety*, Vol. 240, Article No. 109594, doi: 10.1016/j.ress.2023.109594.

[6] Pyles, R.A. (2003). *Aging aircraft: USAF workload and material consumption life cycle patterns*, RAND Corporation, Santa Monica, USA.

[7] Dixon, M.C. (2006). *The maintenance costs of aging aircraft: Insights from commercial aviation*, RAND Corporation, Santa Monica, USA.

[8] Kim, K.-R., Kim, H.-W., Jeong, J., Cha, J.-H., Jeong, D.-S. (2020). Simulation study on the calculation of weapon system's operating maintenance costs to develop LCS-P, *Journal of the Korea Academia-Industrial Cooperation Society*, Vol. 21, No. 9, 82-91, doi: 10.5762/KAIS.2020.21.9.82.
[9] Keating, C., Rogers, R., Unal, R., Dryer, D., Sousa-Poza, A., Safford, R., Peterson, W., Rabadi, G. (2003). System of systems engineering, *Engineering Management Journal*, Vol. 15, No. 3, 36-45, doi: 10.1080/10429247.2003.11415214.
[10] Safaei, N., Banjevic, D., Jardine, A.K.S. (2011). Workforce-constrained maintenance scheduling for military aircraft fleet: A case study, *Annals of Operations Research*, Vol. 186, No. 1, 295-316, doi: 10.1007/s10479-011-0885-4.
[11] Aramon Bajestani, M., Beck, J.C. (2013). Scheduling a dynamic aircraft repair shop with limited repair resources, *Journal of Artificial Intelligence Research*, Vol. 47, 35-70, doi: 10.1613/jair.3902.
[12] Mattila, V., Virtanen, K. (2014). Maintenance scheduling of a fleet of fighter aircraft through multi-objective simulation-optimization, *Simulation*, Vol. 90, No. 9, 1023-1040, doi: 10.1177/0037549714540008.
[13] Zhang, Q., Liu, Y., Xiahou, T., Huang, H.-Z. (2023). A heuristic maintenance scheduling framework for a military aircraft fleet under limited maintenance capacities, *Reliability Engineering & System Safety*, Vol. 235, Article No. 109239, doi: 10.1016/j.ress.2023.109239.
[14] Vollmann, T.E., Berry, W.L., Whybark, D.C., Jacobs, F.R. (2005). *Manufacturing planning and control systems for supply chain management*, 5th edition, McGraw-Hill, New York, USA.
[15] Olhager, J., Rudberg, M., Wikner, J. (2001). Long-term capacity management: Linking the perspectives from manufacturing strategy and sales and operations planning, *International Journal of Production Economics*, Vol. 69, No. 2, 215-225, doi: 10.1016/S0925-5273(99)00098-5.
[16] Bunecke, K., White, E.D., Ritschel, J.D., Bush, B.A. (2018). Evaluating annual fixed wing maintenance costs, *Defense Acquisition Research Journal*, Vol. 25, No. 3, 244-263, doi: 10.22594/dau.18-797.25.03.
[17] Blanchard, B.S. (2004). *System engineering management*, 3rd edition, John Wiley & Sons, New York, USA.
[18] Kullstam, P. (1981). Availability, MTBF and MTTR for repairable M out of N system, *IEEE Transactions on Reliability*, Vol. R-30, No. 4, 393-394, doi: 10.1109/TR.1981.5221134.
[19] Sharma, R.K., Kumar, S. (2008). Performance modeling in critical engineering systems using RAM analysis, *Reliability Engineering & System Safety*, Vol. 93, No. 6, 913-919, doi: 10.1016/j.ress.2007.03.039.
[20] Bányai, Á. (2023). Impact of agile, condition-based maintenance strategy on cost efficiency of production systems, *Advances in Production Engineering & Management*, Vol. 18, No. 3, 317-326, doi: 10.14743/apem2023.3.475.
[21] Peng, J., Liu, B., Liu, Y., Xu, X. (2020). Condition-based maintenance policy for systems with a non-homogeneous degradation process, *IEEE Access*, Vol. 8, 81800-81811, doi: 10.1109/ACCESS.2020.2991590.
[22] Chen, Y., Gong, W., Xu, D., Kang, R. (2018). Imperfect maintenance policy considering positive and negative effects for deteriorating systems with variation of operating conditions, *IEEE Transactions on Automation Science and Engineering*, Vol. 15, No. 2, 872-878, doi: 10.1109/TASE.2017.2675405.
[23] Alrabghi, A. (2025). A modelling approach for asset degradation: Advancing digital twin in maintenance, *International Journal of Simulation Modelling*, Vol. 24, No. 1, 76-86, doi: 10.2507/IJSIMM24-1-715.
[24] Jeang, A., Ko, C.P., Chung, C.-P., Chen, Y.-J., Lin, I. (2019). Optimal availability for determining choice and repair policy of system components, *International Journal of Quality & Reliability Management*, Vol. 36, No. 3, 347-357, doi: 10.1108/IJQRM-12-2017-0255.
[25] Fadaeefath Abadi, M., Bordbari, M.J., Haghighat, F., Nasiri, F. (2025). Dynamic maintenance cost optimization in data centers: An availability-based approach for K-out-of-N systems, *Buildings*, Vol. 15, No. 7, Article No. 1057, doi: 10.3390/buildings15071057.
[26] Albino, V., Carella, G., Okogbaa, O. (1992). Maintenance policies in just-in-time manufacturing lines, *International Journal of Production Research*, Vol. 30, No. 2, 369-382, doi: 10.1080/00207549208942900.
[27] Selech, J., Matijosius, J., Kilikevicius, A., Marinkovic, D. (2025). Reliability analysis and the costs of corrective maintenance for a component of a fleet of trams, *Tehnički Vjesnik – Technical Gazette*, Vol. 32, No. 1, 205-216, doi: 10.17559/TV-20241121002144.
[28] Al-Turki, U. (2011). A framework for strategic planning in maintenance, *Journal of Quality in Maintenance Engineering*, Vol. 17, No. 2, 150-162, doi: 10.1108/13552511111134583.
[29] Turan, H.H., Elsawah, S., Ryan, M.J. (2020). A long-term fleet renewal problem under uncertainty: A simulation-based optimization approach, *Expert Systems with Applications*, Vol. 145, Article No. 113158, doi: 10.1016/j.eswa.2019.113158.
[30] Adamides, E.D., Stamboulis, Y.A., Varelis, A.G. (2004). Model-based assessment of military aircraft engine maintenance systems, *Journal of the Operational Research Society*, Vol. 55, No. 9, 957-967, doi: 10.1057/palgrave.jors.2601756.
[31] Park, J., Moon, S., Choi, J. (2022). Planned maintenance queue simulation based on failure probability: Focused on the naval battleship, *Journal of the Korean Institute of Industrial Engineers*, Vol. 48, No. 1, 105-116, doi: 10.7232/jkiie.2022.48.1.105.
[32] Forrester, J.W. (1969). *Urban dynamics*, MIT Press, Cambridge, USA.
[33] Sterman, J.D. (2000). *Business dynamics: Systems thinking and modeling for a complex world*, McGraw-Hill, New York, USA.