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A SYSTEM DYNAMICS MODEL OF TRAVELED WORK

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ABSTRACT

In commercial airplane manufacturing and assembly, “traveled work” refers to jobs which are delayed and/or completed in a factory location other than what was originally planned. Traveled work takes longer to complete in terms of labor hours, and incomplete work can interfere with operators’ ability to complete other planned work causing cascading delays. Reducing or eliminating traveled work is often targeted as a cost reduction measure.

A system dynamics model was created to simulate the propagation of traveled work from an airplane final assembly line to the airport ramp where final preparation for delivery is completed. Instead of considering work at the level of fidelity of individual jobs (as in Discrete Event Simulation), jobs are aggregated into stocks with other related jobs in a ‘top down’ approach. The model thus avoids DES’s requirement for a complete and accurate job precedence network. Simulation results point to high-leverage policy changes which may reduce traveled work and reduce cost.

1 INTRODUCTION

The purpose of this project was to better understand the systemic causes of traveled work in an airplane production system. The final assembly line has multiple work locations, or “positions,” where tooling and other considerations require that work be performed. Airplanes are pulsed along the line at a regular cycle time. If a job is not completed within the cycle time, it “travels” to the next position, or to the airport ramp if the airplane’s scheduled time in the factory is complete.

2 TECHNICAL APPROACH

System dynamics modeling and discrete event simulation were both considered for the application. System dynamics modeling was chosen for two reasons: first, the desire to explore high-level systemic drivers of the problem to identify strategic changes; and second, incomplete job precedence network information which would have significantly reduced confidence in the results of a bottom-up DES approach. The target model is more quantitative in nature than a traditional system dynamics model and built at a higher level of abstraction than a typical DES model.

A Vensim model was constructed to simulate the propagation of traveled work. At the core of the model is inflow and outflow of work in one position (as seen in Figure 1). At each line pulse, a randomly varying amount of planned work is loaded into the airplane at a given position. Mechanics work jobs at a variable rate depending on fatigue, the type of work, and other factors. Any unfinished work is passed to the next position at the next line pulse. Traveled work thus accumulates within the system and propagates downstream to the field. Managers may adjust worker headcount and scheduled hours in order to compensate for increasing levels of traveled work.

The model was designed to couple closely with data analytics. Production data systems provided broad, systemic model inputs for fine-grained locations and teams in the factory, enabling comparison of the impact of traveled work on different kinds of tasks and teams without the need for gathering additional time data specific to the modeling effort. System dynamics modeling also demands an understanding of historical trends to inform model structure. Data analytics provided a retrospective window that traditional time study and observational methods could not have easily duplicated.

Furthermore, the model captured the impact of data analytics on business decisions themselves. Business logic in the model, including employee scheduling and hiring rules, was structured as a feedback control law based on the actual metrics provided to managers in visibility dashboards used for daily tactical decision making. In this way, the systemic impact of the way metrics are calculated and presented may be examined.

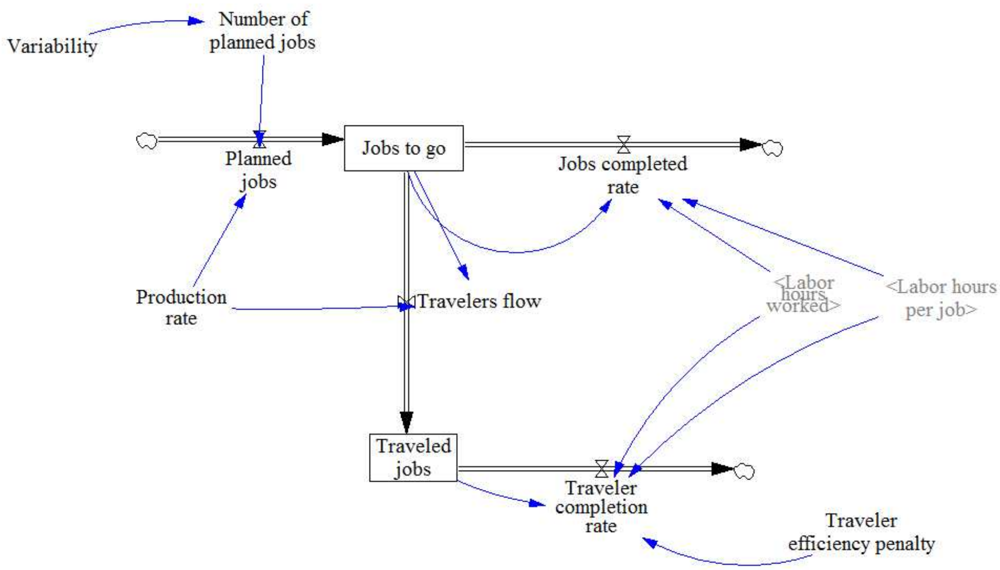

Figure 1: Stocks and flows of jobs – the central model process

3 RESULTS

The Vensim model produces realistic values under present conditions for the two central variables (traveled work and headcount). The model also produces dynamics consistent with historical system behavior, such as the period of oscillations and impact of step changes in production rate. Three areas of potential change were evaluated for their impact on travelers: hiring policies, budgeting practices, and incoming task variability. Specific, high-leverage improvements were identified in two of these categories.

4 CONCLUSIONS

System dynamics modeling was a successful approach for evaluating systemic causes of traveled work and pointing to potential solutions. Incorporating data analytics into the model design from the beginning significantly reduced the amount of time required to develop the model and resulted in a model applicable to the entire production line as well smaller, more granular areas of the factory. Constructing business logic based on real-world metrics resulted in seemingly accurate system behavior and the potential for identifying any adverse incentives built into the metrics themselves.

While the Vensim model is valuable for fostering conversations about high level strategy, the model was not as useful as expected for day-to-day tactical predictions of traveled work, which is highly state dependent and variable; this presented initialization problems which limited the accuracy of the first few airplanes of each simulation run.