Balancing Robustness and Flexibility in Transportation Networks

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Can both levers be coordinated to create the right level of resilience despite unforeseen changes in the environment, such as lead time delays, demand fluctuations or network failures?

Traditional transportation planning (determining how many units of which asset type to use in what locations within your network) is usually conducted using a deterministic optimization-based tool. The costs of each potential option are calculated and the lowest-cost solution that meets the required expected service levels is selected.

This approach is widely used for transportation network design, procurement and scheduling problems because it works well. The tool provides a great mechanism for consolidating massive amounts of data and arriving at the best decision based on a seemingly unlimited number of potential options. In other words, it truly finds the "optimal" solution.

However, it is well understood that this traditional approach has two major flaws. First, the analysis assumes values for all input variables. This means that if the model is determining which truckload carriers to assign to a lane of traffic, the exact number of expected loads must be known. However, in practice, these forecasts tend to be very inaccurate, especially at the disaggregated lane level. The second flaw is that the solutions from these models are often quite fragile. That is, if any of the underlying assumed input values change, then the originally "optimal" plan might end up costing much more than anticipated.

These two weaknesses have led transportation planners to try to design more robust transportation plans. Robustness is the ability of a system to operate efficiently and effectively despite a wide range of unforeseen changes in the environment, such as lead time delays, demand fluctuations, or network failures. A simple example in transportation planning is to keep extra capacity on hand (adding more trucks to the private fleet, assuming a lower loading capacity, etc.) to the system.

Adding robustness to a system has a long history in logistics. Maintaining a safety stock of inventory in case of spikes in demand or delayed replenishment is essentially a way to increase the system robustness. Whenever a planner is adding robustness to a plan they are essentially following Benjamin Franklin's advice that "an ounce of prevention is worth a pound of cure." It is better to build a plan that can sustain unforeseen changes than react and respond to the change after it happens.

Most managers in operational roles follow Franklin's advice. A worldwide survey of supply chain managers conducted by MIT CTL specifically asked whether the respondents thought it was more important to prevent a risk from occurring (prevention) or to better react to the risk as it occurs (cure). On a scale of 1 to 5 where 1 indicated prevention is much more important and 5 indicates that the cure is much more important, the average response was 2.41. The average was essentially on robust or preventative side of the middle. More interesting, though, we found that this "Franklin" measure of how to respond to risk differed by age, geography and job function.

A finding that is of particular relevance to this article is that transportation planners had an average response of 3.1—the highest of any function! This confirms the general consensus that the transportation function is often the tail on the end of the dog—forced to react to changes they cannot control or necessarily foresee.

So, while transportation planners tend to build in robustness, in practice, transportation managers tend to be emergency responders or firemen putting out each day's fires. Historically, there are several ways to build flexibility into a system. For example:

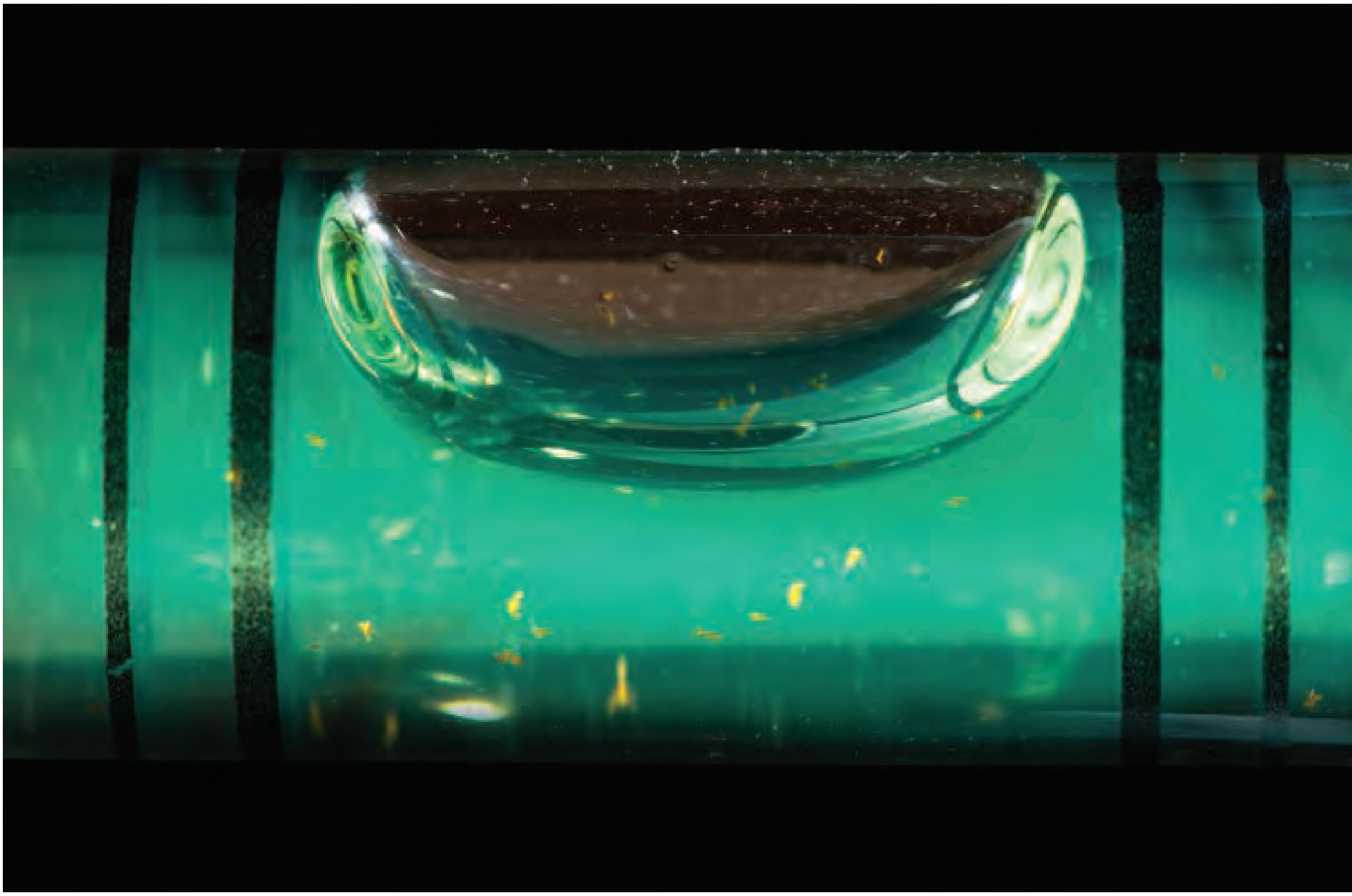
• In aircraft routing, creating shorter cycles with fewer legs tends to make the network less susceptible to disruptions. Longer tours have an increased probability of being disrupted and are harder to recover from. Creating shorter tours makes "swaps" a lot easier to manage in real time if one vehicle fails. This is similar to vehicle routing where tours with fewer legs are more reliable than longer ones.

• In truck dispatching, loading two 28' pups is more flexible than using a single 53' trailer. While the 53' trailer might have a total lower operational cost assuming there are no changes, the two pups allow for the option of diverting the shipment while in transit. That is, more ability to respond or be flexible.

• Union classification of jobs. Traditional categories for workers within a unionized carrier fall into dock workers, hostlers, local drivers and long-haul drivers. Recently, some LTL carriers have begun working with unions to allow for cross-designations where an employee is classified as a dockworker/driver. These workers, while paid a little more, provide the carrier with flexibility as to how to use them each shift.

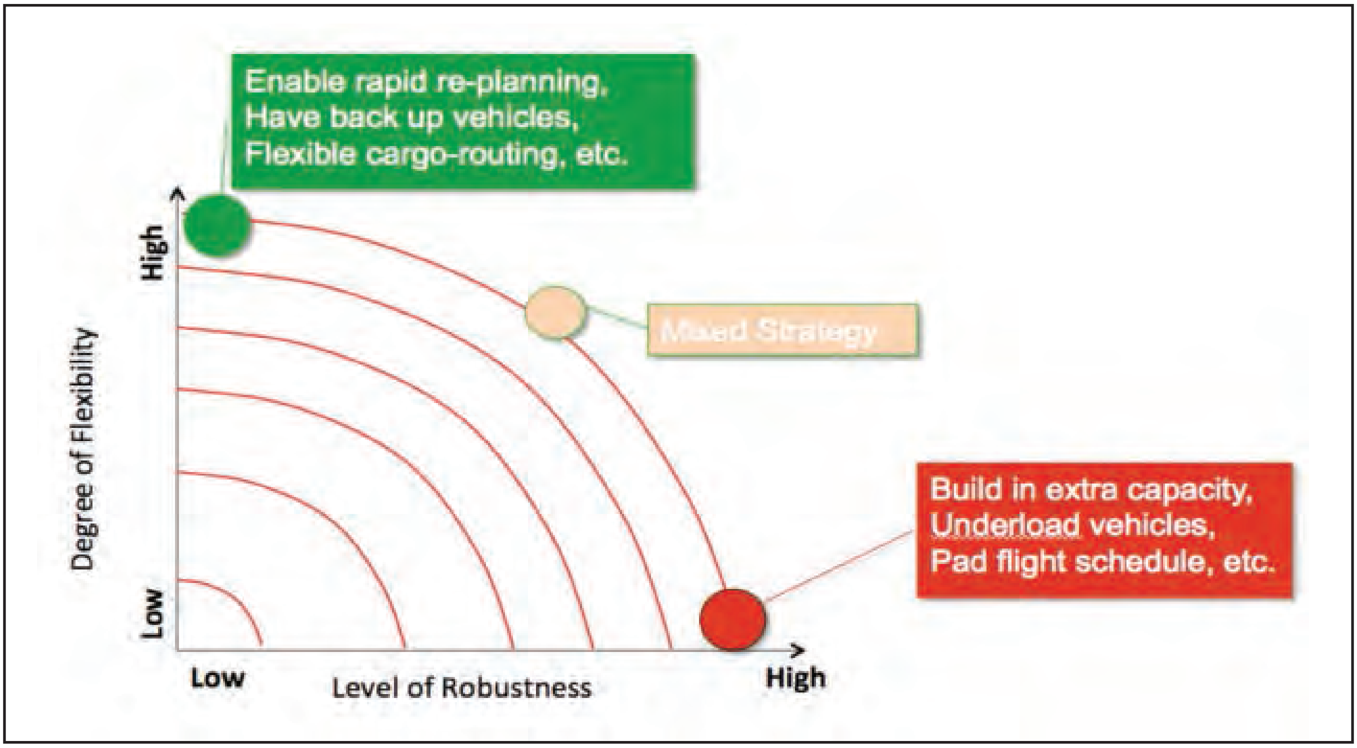
These observations have led the MIT FreightLab research team to investigate whether Ben Franklin was wrong. Does it sometimes make more sense to not spend so much time building a bullet proof plan, and instead to be ready to handle network disruptions and changes when they occur? When is it better to be more flexible or responsive than robust? More specifically, the research team is exploring how an organization can use both robustness and flexibility in order to make a transportation system more resilient.

The research team is developing methods for using both of these levers (robustness and flexibility) in a coordinated fashion to create the right level of resilience for the situation. Two projects illustrate how the project is developing a methodology that will enable firms to better plan: fleet assignment and aircraft planning.



Fleet Assignment

Walmart Stores partnered with MIT to improve their truckload transportation procurement process. Specifically, the combined team designed, developed and implemented a software tool (Fleet Network Optimization Tool or FNOT) to optimally allocate both private fleet and for-hire



carrier assets across Walmart's network considering uncertainty of demand.

FNOT uses a large-scale optimization algorithm that allows planners to determine the optimal allocation of fleet and for-hire carriers. FNOT considers uncertainty in the network demands through the use of either historical demand patterns or a theoretical distribution. The model creates fleet tours that start and end at each of the several dozen domicile locations and comply with Walmart's business preferences and U.S. Department of Transportation's driving rules. Each of these tours represents a candidate solution that is then fed into the model.

The model distributes the lane demand across all of the relevant tours that include any particular lane. By using some clever math, the randomness of the demand volume is captured in the model and traditional optimization methods can be used to solve it. Essentially, the model makes a trade-off between the marginal cost of the fleet and the cost of a third-party carrier for each lane while considering the probability of having an additional load. Essentially, the variability of the demand is taken into account when finding the optimal tour selections.

Implemented in 2011, the tool has reduced required planning time by 75 percent and has led to repeatable savings of $15m to $25m annually. The net effect is that a more robust and resilient fleet plan is developed.

Aircraft planning

Aircraft planning involves determining the size and location of the aircraft fleet, the routing and scheduling of the specific planes, as well as the routing that the cargo takes within the network. Working with a large organization, the MIT FreightLab is developing a methodology for developing a "Living Plan" that is robust and allows for flexibility in operations.

Based on the historical sources of uncertainty, robustness is added to the initial plan in terms of excess capacity and padded lead times. The specific magnitude and location of where to add this redundancy is determined by the historical frequency of delays and volume fluctuations. The plan determines the aircraft fleet size and location as well as both the aircraft and cargo routing.

In order to test how well these new robust plans hold up, the research team is creating a simulation test bed where the plan is subjected to different scenarios. Additionally, different operational flexibilities are enabled. These include allowing cargo re-routing, prioritization of lanes, etc. The idea is to examine how the different forms and levels of robust planning interact with the different flexibility practices.

Additionally, the team is exploring how to imbed certain structure into the robust plan in order to better enable flexibility in operations.

Both of these projects demonstrate two things. First, they show how organizations are trying to develop more resilient transportation plans using a combination of robust and flexible strategies. Second, the projects underline how firms can work with academic researchers to push the boundary of what is solvable.

While we highlighted the technical or analytical problems with developing resilient plans, there are also managerial issues. Any plan that is more resilient will naturally appear to be more expensive up front. It is tempting for some to simply go with the lowest-cost "optimal" solution, but this is equivalent to canceling your insurance to save on premiums. The challenge for managers developing resilient plans is to have the managerial fortitude and the necessary communication skills to convince senior leadership of the need for these imbedded resilience strategies.

Both Dr. Caplice and Dr. Jauffred are part of the MIT FreightLab at the MIT Center for Transportation & Logistics.

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