Shipment Digital Twin Platform

Using Digital Twins to Enable Supply Chain Disruptions Prediction and Mitigation

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What is the Shipm-DT Platform?

The Shipment-Digital Twin (Shipm-DT) Platform is an AI-powered solution that provides supply chain (SC) operators with shipment-specific predictions, recommendations, and insights about critical events—like delays—allowing them to implement timely and effective mitigation strategies and proactively avoid disruptions. As a result, the Shipm-DT Platform enables organizations to reduce the cost of SC disruptions, lower shipment costs, increase SC knowledge and close the gap between planned and actual SC performance.

Early Detection of Critical Events

SC operators can use the Shipm-DT Platform to define an initial Information Heat Map (IHM) that captures the probabilities of various parameters, and their disruption impacts on shipments (Fig. 5). The IHM is built by analyzing earlier critical events, disruptions, SC historical data, environmental conditions, and logisticians' experiences. Next, a virtual, shipment-specific digital twin, the Shipm-DT, is created for each shipment. Based on the IHM, the Shipm-DT defines a shipment-specific model. The Shipm-DT uses the shipment model to continually monitor shipment progress, predict the onset of significant delays, and warn the impacted SC operators as needed. With more information, the Shipm-DT can recommend or initiate corrective actions on its own. In its most advanced form, the Shipm-DT will enable SC operators to simulate alternative mitigation strategies and generate what-if shipping scenarios for different shipments. On the SC operator level, the Information Heat Map (IHM) probabilities are automatically updated based on data provided from all Shipm-DTs connected to it. Once a shipment is completed, the virtual Shipm-DTs are "terminated"; however, their "insights" would still be included in the IHM as revised risk probabilities of possible delay events. Thus, the IHM reflects the SC's real-time, overall risk levels and can be analyzed, validated, and relied on to simulate and automate complex SC decisions.

Shipment-DT Platform in Action

XY is a medium-sized logistics company with clients all around the globe. XY has modern logistics, and advanced business analytics systems that provide diverse information about all aspects of its operations, allowing XY to keep a good track record of meeting promised delivery times. As the COVID pandemic expanded, XY faced several uncertainties that jeopardized the accuracy of its predicted delivery times. As a result, XY—along with its

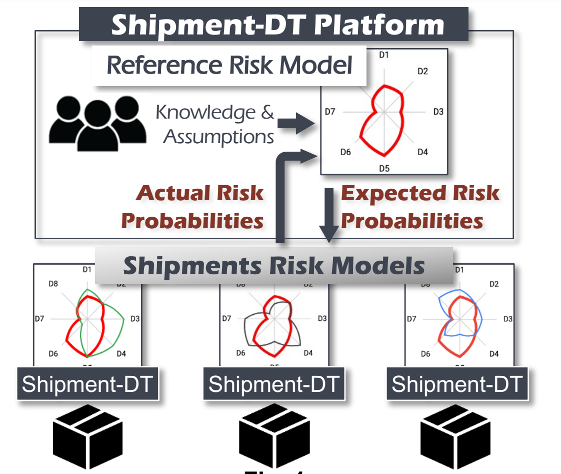

Fig. 1

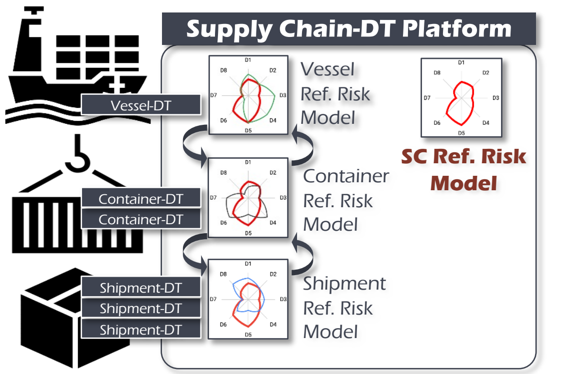

Fig. 2

competitors—had no choice but to increase its delivery estimate margins. XY saw this as an opportunity. Using the Shipm-DT Platform, they were then able to add risk dimensions to their shipment parameters unavailable in their planning systems. This flexibility allowed them to account for the impact of potential disruptions such as actual infection rates at various locations, cross-border restrictions, personnel shortages, etc. (Fig. 3). XY can now anticipate the impact probability of various interruptions on delivery timeframes dynamically, without the need to wait for actual data, based on the experience of its logisticians and market insights. As a result, XY reduced the margins on their projected delivery timeframes, gaining an essential market advantage.

How is the Sh.-DT Platform Unique?

The Shipm-DT Platform is powered by a proprietary Bayesian-based algorithm we call the Semantic Algorithm. The Semantic Algorithm computes, assigns, tracks, and updates probabilities for hundreds of shipment-related parameters and events in near real-time. However, the Shipm-DT Platform's unique feature is the Information Heat Map (IHM), which captures the probabilities associated with specific events for all shipments that have ever been linked to the model. In a mature environment, the IHM reflects what might be referred to as the "Shipment Risk DNA," which stores the updated probabilities of various shipment events for a specific SC. As a result, a delay risk assessment done by a Shipm-DT in Singapore can automatically help improve the risk assessment of another Shipm-DT in Tokyo or Los Angeles, as long as both Shipm-DTs connect to the same IHM. That is, the Shipm-DT Platform provides adaptive crowd intelligence, in which—If desired—risks assessed by one member in a population can be used to help other members update their risk assessment and subsequent decisions for similar events. Furthermore, SC operators can incorporate new facts and assumptions about potential interruptions into the IHM as probabilities of occurrence and reflect them to all relevant Shipm-DTs in real-time, improving risk forecasting accuracy across the entire SC network and ultimately its resilience.

Long-Term Vision

Building a supply chain digital twin (SC-DT) is still challenging. The Shipm-DT Platform's long-term vision is thus to expand its scope to become a SC-DT Platform. In this scenario, Shipm-DTs are used as building blocks to develop Information Heat Map (IHM) for complex SC elements like containers, warehouses, or vessels (Fig. 2). Using similar building blocks to define more complex but different constructs is like how cells in an organism are arranged in various functional configurations to generate diverse organs. Each level or element in the SC-DT is then represented by a different Reference Risk Model, which serves the different DTs connected to it while updating surrounding elements (or nodes) with relevant data as needed. As previously stated, on the SC level, expected higher-level risks, such as vessel level disruptions or weather uncertainty, can be pushed down to the lower-level risk models, causing the various DTs to update the risks for their element.

How To Start?

To begin, we propose—based on historical data—defining an Information Heat Map (IHM) for specific SC delay scenarios (Fig. 5). The IHM provides preliminary predictions and insights regarding factors affecting shipment delays. The IHM also gives additional information about the solution's feasibility, potential, and impact for the scenarios in question, as well as the effort required to build a Shipm-DT Platform.

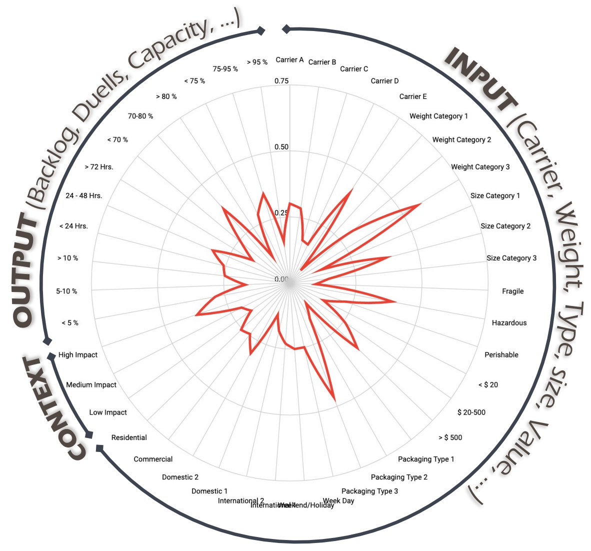

Fig. 3 Information Heat Map structure for shipments establishes a profile of all parameters affecting shipments. The model calculates the probability of each major delay risk characteristic affecting a shipment. The Shipm-DT performs two critical functions: it converts the IHM to a shipment-specific risk model and then updates the IHM with updated risk values, hence improving the overall SC risk assessment.

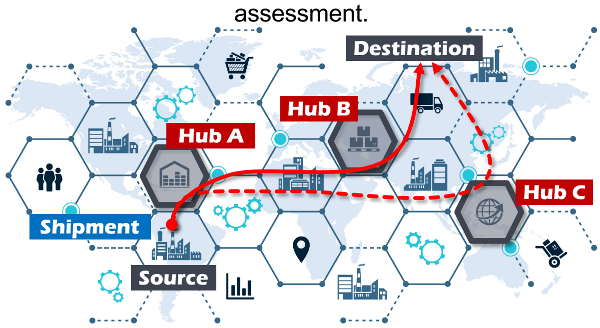

Fig. 4 The Shipm-DT uses the IHM to optimize shipment routing along with the SC. The Shipm-DT predicts precise delivery times and gives efficient routing alternatives in a complex and dynamic supply chain with dozens of carriers, hubs, segments, and routes while considering the impact of unforeseen occurrences in near real-time.

Our Role

We are information architects. Our role is to design the Shipm-DT Platform information architecture necessary to automate the various involved scenarios, design the information architecture of the required Shipm-DTs in support of the various scenarios, and provide the algorithms and logic necessary to optimize the scenarios and enable the platform. Pending patents cover the methods and algorithms that underpin the Shipm-DT Platform (the Information Digital Twin Platform). Supporting concepts are discussed in several research papers (www.orcid.org/0000-0002-2775-6946).

Supply Chain Network

INPUT (Shipment Parameters) / Context				OUTPUT (Hub A Parameters): Hub A Backlog			Transit Time			Hub A Personnel Capacity			Hub A OP Capacity		
				< 5 %	5-10 %	> 10 %	< 24 Hrs.	24 - 48 Hrs.	> 72 Hrs.	< 70 %	70-80 %	> 80 %	< 75 %	75-95 %	> 95 %
				0.286	0.169	0.248	0.259	0.316	0.164	0.236	0.375	0.119	0.286	0.351	0.158
				A	B	C	D	E	F	G	H	I	J	K	L
Carrier	Carrier A	0.300	1	0.086	0.051	0.074	0.078	0.095	0.049	0.071	0.113	0.036	0.086	0.105	0.047
	Carrier B	0.286	2	0.082	0.048	0.071	0.074	0.090	0.047	0.068	0.107	0.034	0.082	0.100	0.045
	Carrier C	0.168	3	0.048	0.028	0.042	0.044	0.053	0.028	0.040	0.063	0.020	0.048	0.059	0.027
	Carrier D	0.160	4	0.046	0.027	0.040	0.042	0.051	0.026	0.038	0.060	0.019	0.046	0.056	0.025
	Carrier E	0.407	5	0.116	0.069	0.101	0.106	0.129	0.067	0.096	0.153	0.048	0.116	0.143	0.064
Weight	Weight Category 1	0.063	6	0.018	0.011	0.016	0.016	0.020	0.010	0.015	0.023	0.007	0.018	0.022	0.010
	Weight Category 2	0.310	7	0.089	0.053	0.077	0.080	0.098	0.051	0.073	0.116	0.037	0.089	0.109	0.049
	Weight Category 3	0.565	8	0.161	0.096	0.140	0.147	0.178	0.093	0.134	0.212	0.067	0.161	0.198	0.089
Size	Size Category 1	0.128	9	0.037	0.022	0.032	0.033	0.040	0.021	0.030	0.048	0.015	0.037	0.045	0.020
	Size Category 2	0.375	10	0.107	0.064	0.093	0.097	0.118	0.061	0.089	0.141	0.045	0.107	0.131	0.059
	Size Category 3	0.148	11	0.042	0.025	0.037	0.038	0.047	0.024	0.035	0.055	0.018	0.042	0.052	0.023
Type	Fragile	0.099	12	0.028	0.017	0.025	0.026	0.031	0.016	0.023	0.037	0.012	0.028	0.035	0.016
	Hazardous	0.394	13	0.113	0.067	0.098	0.102	0.124	0.065	0.093	0.148	0.047	0.113	0.138	0.062
	Perishable	0.219	14	0.063	0.037	0.054	0.057	0.069	0.036	0.052	0.082	0.026	0.063	0.077	0.035
Value	< $ 20	0.143	15	0.041	0.024	0.035	0.037	0.045	0.023	0.034	0.054	0.017	0.041	0.050	0.023
	$ 20-500	0.258	16	0.074	0.044	0.064	0.067	0.081	0.042	0.061	0.097	0.031	0.074	0.090	0.041
	> $ 500	0.353	17	0.101	0.060	0.088	0.092	0.111	0.058	0.083	0.132	0.042	0.101	0.124	0.056
Packaging	Packaging Type 1	0.099	18	0.028	0.017	0.025	0.026	0.031	0.016	0.023	0.037	0.012	0.028	0.035	0.016
	Packaging Type 2	0.153	19	0.044	0.026	0.038	0.040	0.048	0.025	0.036	0.057	0.018	0.044	0.053	0.024
	Packaging Type 3	0.462	20	0.132	0.078	0.115	0.120	0.146	0.076	0.109	0.173	0.055	0.132	0.162	0.073
Shipping Day	Week Day	0.250	21	0.071	0.042	0.062	0.065	0.079	0.041	0.059	0.094	0.030	0.071	0.088	0.039
	Weekend/Holiday	0.250	22	0.071	0.042	0.062	0.065	0.079	0.041	0.059	0.094	0.030	0.071	0.088	0.039
Destination	International 1	0.231	23	0.066	0.039	0.057	0.060	0.073	0.038	0.055	0.087	0.027	0.066	0.081	0.036
	International 2	0.187	24	0.053	0.032	0.046	0.048	0.059	0.031	0.044	0.070	0.022	0.053	0.066	0.030
	Domestic 1	0.128	25	0.037	0.022	0.032	0.033	0.040	0.021	0.030	0.048	0.015	0.037	0.045	0.020
	Domestic 2	0.304	26	0.087	0.052	0.076	0.079	0.096	0.050	0.072	0.114	0.036	0.087	0.107	0.048
Delivery Address	Commercial	0.245	27	0.070	0.042	0.061	0.064	0.077	0.040	0.058	0.092	0.029	0.070	0.086	0.039
	Residential	0.255	28	0.073	0.043	0.063	0.066	0.081	0.042	0.060	0.096	0.030	0.073	0.090	0.040
Weather (Context)	Low Impact	0.180	29	0.052	0.031	0.045	0.047	0.057	0.030	0.043	0.068	0.021	0.052	0.063	0.028
	Medium Impact	0.204	30	0.058	0.035	0.051	0.053	0.064	0.033	0.048	0.076	0.024	0.058	0.071	0.032
	High Impact	0.371	31	0.106	0.063	0.092	0.096	0.117	0.061	0.088	0.139	0.044	0.106	0.130	0.059

Fig. 5 An example of an Information Heat Map (IHM) for hypothetical supply chain with shipments delay. The "Input" represents the shipment parameters, while the "Output" indicates the parameters unique to each node of interest along the supply chain. An actual model can incorporate hundreds of parameters related to shipments, context, and nodes. The IHM is defined to manage a specific event, in this case, shipments delay. Our algorithm then relies on historical data to assign a probability to each parameter which indicates **how well that parameter predicts a shipment delay** (Fig. 3 represents these various probabilities in one view.)

Many of these probabilities provide direct insights into the delay risk, for example:

- Line 17—A delivery worth more than $500 is projected to be delayed 35.3% of the time.
- Column I—When Hub A is working at more than 80% of its personnel capacity, a shipment going through that hub is expected to still have a 11.9% probability of missing the promised delivery date.
- Line 31—During severe weather, there is a 37.1% chance that a shipment will be delayed.

However, a shipment delay is usually affected by hundreds of dependent parameters. Identifying how such parameters interact to predict the optimal shipment-route configuration and minimize delays is thus a challenging task, made all the more difficult when undertaken under constantly changing conditions, lack of information and with limited decision-making time. This is where the Shipment Digital Twin (Shipm-DT) comes into play: it continuously calculates the complex probabilities associated with a shipment to forecast its delay risk. The Shipm-DT also learns how the various parameters interact and influence one another and uses the learned dependencies to improve the delay predictions. Further, the Shipm-DT relies on decision logic and algorithms to provide recommendations for the optimal configuration of a shipment-route combination to minimize delays.

In comparison to the shipment IHM, a SC Reference Information Heat Map (SC IHM) would capture dozens of SC events, not just delays. In this situation, the SC IHM is a multi-dimensional information cube that provides the bearing of a parameter—for example, shipment weight—on predicting a variety of events (e.g., delays, cost factors, perfect order rates, etc.) The SC-DT would then rely on the SC IHM to monitor the SC, predict deviations from planned performance and provide insights into mitigation and optimization.