

An Online Decision Support Framework for Managing Abnormal Supply Chain Events

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Abstract

Enterprises today have acknowledged the importance of supply chain management to achieve operational efficiency, and cutting costs while maintaining quality. Uncertainties in supply, demand, transportation, market conditions, and many other factors can interrupt supply chain operations, causing significant adverse effects. These uncertainties motivate the development of simulation models and decision support system for managing disruptions in the supply chain. In this paper, we propose a new agent-based online decision support framework for disruption management. The steps for disruption management are: monitoring the KPIs, detecting the root cause for the deviation of KPIs, identifying rectification strategies, finding the optimal rectification strategy and rescheduling operates as necessary in response to the disruption. The above framework has been implemented as a decision support system and tested on a refinery case study.

Keywords: Risk Management, Optimization, Agent-Based, Uncertainty

1. Introduction

In the face of highly competitive global markets, companies are pressurized to reduce costs and increase efficiency. As a consequence, they are employing new strategies which result in complex supply chains. These strategies include outsourcing, single sourcing, and centralised distribution. An efficient supply chain requires transparency among its constituent entities. Complex and lengthy supply chains lack visibility and this leads to disruptions.

Unhindered and timely material, information and finance flow between different entities of supply chain is another important element. Blockage in any of these would lead to undesirable events like process shutdown, financial loss, under-supply or over-supply, etc. Hence there is a greater need for risk and disruption management.

A disruption management system should be capable of detecting abnormal situations before they occur, diagnose the root cause, and propose corrective actions as required. While a complete rectification is desirable, in cases where the effect of disruption is

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manifested very late, it may only be feasible to effect a partial recovery. A robust system should be capable of handling both complete and partial rectification.

The challenges involved in developing disruption management system are: 1) Supply chain entities are dynamic, disparate and distributed; and 2) they are tightly linked at intra- and inter-enterprise levels and affect the performance of one another. These make the detection of disruption and the root cause difficult. Further, complex rectification strategies are needed to partially or completely overcome the disruption. For example, the implementation of a rectification strategy in some cases will need rescheduling of operations.

In this paper, we propose an agent-based framework for disruption management. Intelligent agents measure key performance indicators in each supply chain entities. Disruptions are detected when these KPIs deviates from a pre-specified set points or when unplanned events are detected. Root causes are diagnosed using a causal model. Rectifications are proposed and optimised through a model of supply chain linkage. When necessary, rescheduling is performed to recover from a disruption. In this paper, we present the details of the framework and its implementation and illustrate it using a refinery supply chain.

1.1 Literature Review

There is limited literature in the area of disruption management; no general structured methodology exists to date. Sheffi et al. (2003) describe mechanisms which companies follow to assess terrorism-related risks, protect the supply chain from those risks and attain resilience. They provide classifications of disruptions, security measures and ideas to achieve resilience. They report various case studies and interviews with executives of companies. Wilson (2003) focuses only on transportation disruptions. Julka et al (2002; a, b) proposed an agent-based framework for modelling a supply chain. In their framework, the behaviour of every entity in the supply chain is emulated using an agent that imitates the behaviour of various departments in refinery. Mishra et al. (2003) reported an agent-based decision support system to manage disruptions in a refinery supply chain. In the event of a disruption, agents collaborate to identify a holistic rectification strategy using heuristic rules. In this paper, we generalize their approach and develop a model-based framework for managing supply chain.

2. Framework and Methodology for Disruption Management

The proposed framework is described in Figure 1 and is capable of handling situations where 1) occurrence of a disruption is manifested only through deviations from set point and the root cause is not observable, as well as 2) cases when disruptions can be detected at source i.e., the root cause is observable. From control theory, the former needs feedback control while the latter requires a feedforward mechanism.

In the general case, the steps for disruption management are carried out by the following components:

1. **KPI Monitors:** To manage disruptions in supply chain, it is essential to measure key performance indicators (KPIs) and to identify their effect on the supply chain. We use stock inventory, throughput, and other similar indicators to monitor the state of each constituent of the supply chain. These can be measured at regular intervals and

monitored by comparing their day-to-day values against pre-specified limits. Alarms are generated when a sustained deviation in any KPI is detected.

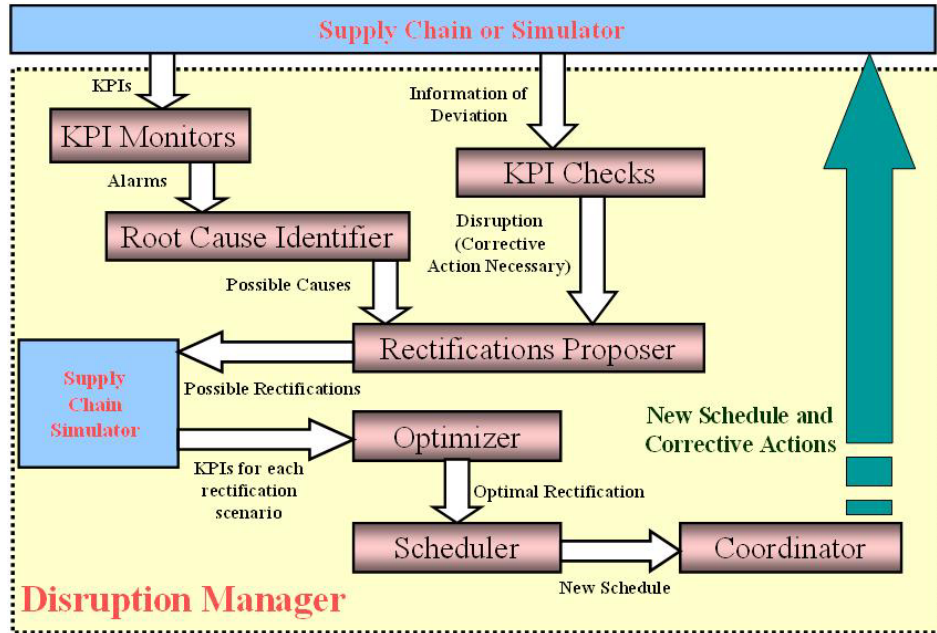


Figure 1. Framework for disruption management system

2. Root Cause Identifier: Causal models are used to identify the possible causes for the alarms. Hypotheses are proposed to identify the root cause and confirmed if all expected consequences are manifested online.
3. Rectifications Proposer: The list of corrective actions to rectify the root cause is generated using a causal model, which accounts for the linkages among the supply chain entities. Each rectification strategy is simulated using a supply chain simulator and feasibility and KPIs for each scenario is evaluated.
4. Optimizer: One rectification strategy is selected based on feasibility and KPIs.
5. Scheduler: In a general case, disruption may make the existing operation schedule infeasible or sub-optimal. Optimal rectification strategy may require rescheduling of operations. Our rescheduling scheme is described in more detail in Section 2.1.
6. Coordinator: Numerous activities may be necessary to partially or completely rectify the disruption. The implementation of these rectification strategies can be coordinated by this agent.

All the above steps are necessary for disruptions whose root cause is not observable. In cases where the root cause is observable, the occurrence of abnormal event triggers a comparison with KPIs. If corrective actions are found necessary steps 3 to 6 described above are implemented.

2.1 Methodology for rescheduling

Our rescheduling approach is described in Figure 2. Implementation of the optimal rectification strategy may require changes which affect the original schedule, i.e. some operations may be cancelled or rescheduled and new operations may be necessary. These changes are reconciled with the original schedule by the scheduler agent. New schedules are generated based on heuristics taking into account relevant data from the plant hardware model. The evaluator calculates the profit of each new schedule so that the best one can be implemented.

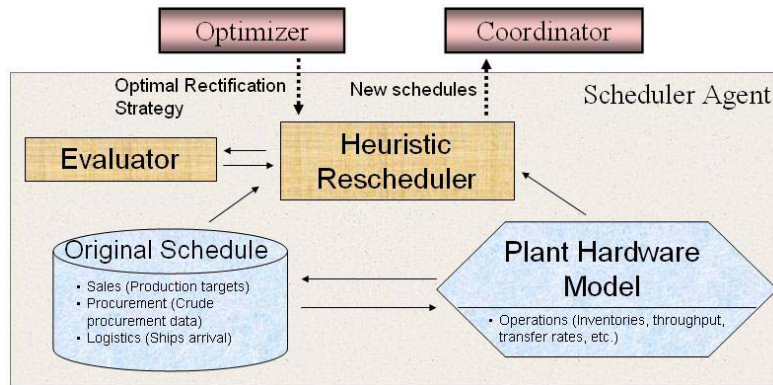


Figure 2. Scheduler agent of the disruption system

The rescheduler uses a heuristic multi-step block preservation strategy. An operation spanning one or more periods is considered a block if it involves no intervening change in configuration. As a corollary, adjacent blocks are separated by a change in configuration. Our approach seeks to minimize changes to blocks. First, feasibility of the disrupted schedule is checked. Second, a heuristic rescheduling strategy is employed to improve optimality of the disrupted schedule for each type of disruption. Five types of disruption have been considered: ship arrival delay, SBM/jetty unavailability, tank unavailability, equipment unavailability, and demand change. To deal with ship arrival delays, relative positions of the blocks of operation as mapped by the original schedule are maintained while adjusting the lengths of the blocks and the volumes involved in the blocks. In response to unavailability of equipment (e.g. pumps, tanks, CDUs, etc.), alternate processing strategies that can retain the blocks of operation from the original schedule are sought. To handle changes in demands, the relative positions of the blocks are kept while adjusting the volume involved in the blocks. The key here is to preserve the characteristic of the original schedule, which is the map of the blocks of operations scheduled. Finally, the objective value of the new schedule is evaluated.

3. Case Study

We have implemented the above framework as a decision support system in Gensym's G2 expert system shell. In this section, we illustrate it using a case study derived from the supply chain of a Singapore refinery. Consider the scenario where there is a sudden increase in demand starting from the 41st day. Operation therefore increases throughput

immediately. As a consequence, the KPI monitor finds that the crude oil inventory for the 42nd day has gone low and generates an alarm. The root cause identifier finds out the possible causes of the deviation: raw material delay, high demand of products, or the efficiency of process decreases such that more crude oil is required. Comparison of the actual and planned ship arrival indicates that there is no arrival delay. Similarly, a check with the operation department reveals that there is no problem with the efficiency of process. Further check with the sales department indicates that the demand is higher than previously projected by 330 kbbl. The diagnosis agent thus confirms the root cause for the low inventory alarm to be a new order on the 41st day. The rectification proposer agent finds two possible rectifications: 1) postponement of other orders, and 2) emergency crude procurement. The optimizer agent evaluates the two options and flags emergency crude procurement of 330 kbbl to arrive on the 44th day as the optimal rectification strategy. The flow of events in this case study is shown in Figure 3. The optimal rectification strategy is then passed to the scheduler agent who reschedules the operation as shown in Figure 4 and 5. The new schedule (Figure 5) includes the emergency crude and deals with the increase in demand by rescheduling operations.

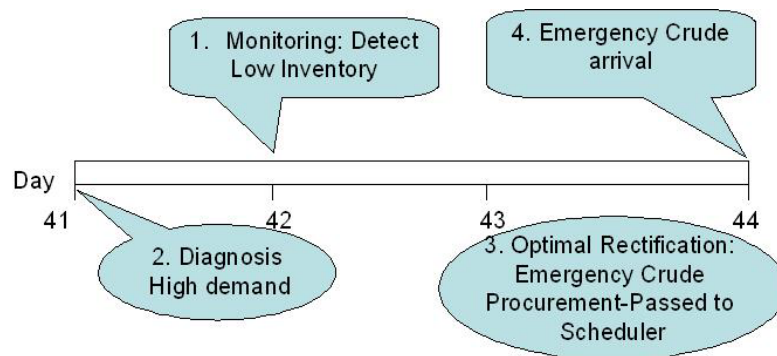


Figure 3. Event flow for the case study

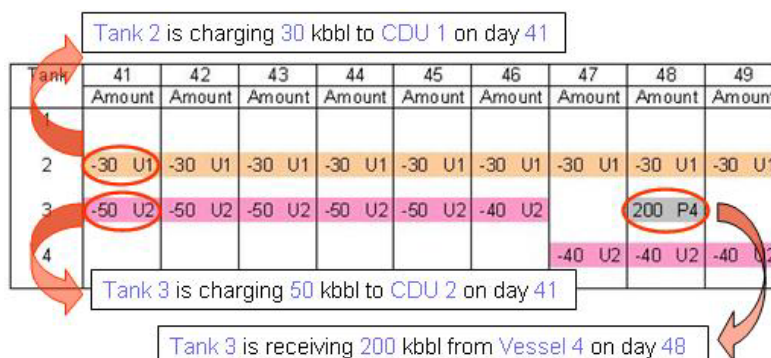


Figure 4. Original operation schedule

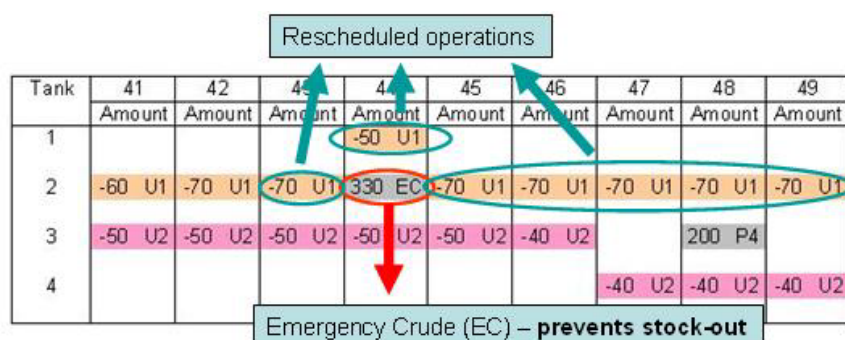


Figure 5. New operation schedule including emergency crude

4. Conclusions

Disruptions are common in supply chains. In this paper, we proposed a systematic framework for disruption management. One key advantage of the proposed approach is that it can handle a wide variety of disruptions, whether due to supplier, transport, operation, or customer problems. The success of this method is predicated on the accuracy of the supply chain model. Our current work is directed towards improving robustness of the approach.

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