

# Dynamic Logistics Model for Optimal Delivery

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## Abstract

This paper deals with the development of dynamic based logistics model aims at optimal delivery. A total logistics model covering five sub-models, namely raw material stock, production process, production stock, production order, and delivery, are proposed. Such models would, in general, require a firm control of the availability of each production components in any of in-flow stage (e.g., raw materials), processing stage (e.g., production), and outflow stage (e.g., production stock, order process, and delivery), to achieve customer satisfaction. It is, however, realized that equilibrium among the three stages is the key success of good logistic systems, but in reality discrepancies among them are hard to avoid. In this research a near-equilibrium situation may be achieved through a dynamic simulation process of the sub-models characterizing their performance as well as their interrelations. This sort of simulation can be considered further as an optimal control for delivery through which a sensitivity trends may provide strategies to producer of how to manage resource with best service. In this very early approach formulation of an objective function that maximizes revenue of sales is determined to cover the market demand. Furthermore, in the form of dynamic simulation model various strategies may be exposed to decide the best policy of delivery.

## 1. Introduction

Many logistic processes are concerned with the balance among the sub-systems of how to get sufficient raw materials put in the stock, how to guarantee production process composed by the availability of raw materials and readiness of production tools, of how to keep production in secure place and ready to be delivered, of how to manage customer orders and provide them with tolerable service level of

delivery [Ballou, 1999]. Failure to maintain such equilibrium would create late delivery at front-end of logistic system and customer dissatisfaction (i.e., late delivery). There have been eminent ideas of how to solve such logistic problem in many research works, but none has discussed the interrelations among the sub-systems in dynamic manners. The system dynamic approach to control logistic systems is very important in order to represent its interrelation, and how a feedback from one sub-system to the other(s) could be elaborated to search optimal performance.

In this research the dynamic based logistics model aims at optimal delivery is developed. A total logistics model covering five sub-models, namely raw material stock, production process, production stock, production order, and delivery, are proposed. Such models would be determined as control system for the availability of each production components in any of in-flow stage (e.g., raw materials), processing stage (e.g., production), and outflow stage (e.g., production stock, order process, and delivery), to achieve customer satisfaction. This proposed model is then transformed in the dynamic simulation to represent the characteristics and interrelation of the sub-models through sensitivity or discrepancies of the sub-models can be learnt and elaborated. This elaboration may further provide producer to introduce his/her strategy in satisfying customer with good delivery. Indeed there might be plenty of possibilities in the determining the objective of delivery strategy, however, in this very early formulation the objective function is defined as to maximize the revenue of sales to cover the market demand.

In the ensuing sections, paper would discuss the rationale of model in section 2, development of dynamic logistics model in section 3, and some simulation expose through which a trend of certain scenario of delivery may result in is discussed section 4. Finally section 5 would conclude the discussion.

## **2. Rationale of the Model**

The proposed model has embedded from the emerging paradigm of designing the transportation systems in a dynamic manner [Ran and Boyce, 1999]. In the structure Ran and Boyce discussed that the equilibrium within the transportation network that represents somehow the choice behavior of road users may require dynamic control systems. Furthermore, as complete system transportation may evolve from the socio-economic activities as suggested by Manheim [1979], by which the flow of vehicles in the road network can be indicated as indicator of performance of the system. As part of transportation systems, logistics eminently represent the intact sub-systems of models explained in section 1, and in more explicit term it does represent the fabrication of raw materials, production machine and human characteristics in performing the socio-economic activity discussed by Manheim.

In this section implication of such rationale would be explained in two stages that is by the macro level of dynamic interaction and socio-economic activities, and the relevant derivation of such rationale at micro level of logistic system.

## 2.1. System Dynamics in Socio-Economic Activities and Transport Systems

As illustrated in Figure 1, the dynamic interrelation between socio-economic activities and transportation system in the context of physical distribution or logistics can be determined as continuous model in which the interaction would result in flow of freight in tonnages of commodities or vehicles.

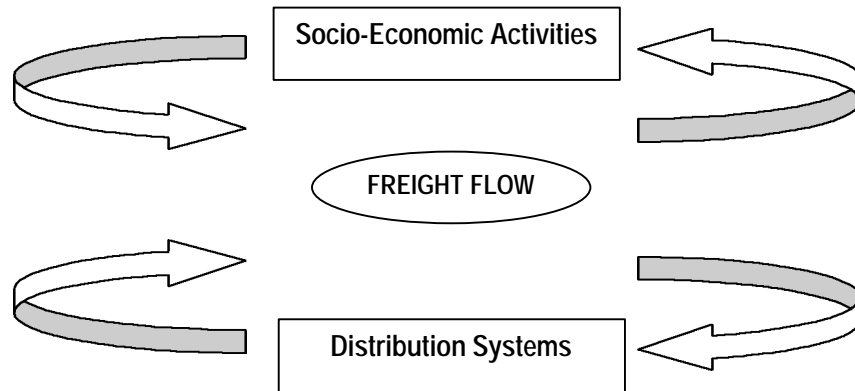


Figure 1: Dynamic Interrelation of Socio-Economic Activities and Distribution Systems

Freight flow in some extent may denote performance or service level of the distribution systems. If the performance is good then activities may likely increase their quantity and quality which may further require more capacity of distribution systems, and so on. If, however, the distribution systems do not perform as what expected by the increase of socio-economic activities it may create reduction impact to the activities. Such more and less movement would achieve certain level of equilibrium which may be understood that none of the sub-systems mentioned above could develop unlimitedly.

The interesting phenomenon in the interaction above is that level of service provides feedback to the both sub-systems either to move forward or to remain, and this evolves by time. So it is obvious that such phenomenon can only be handled or controlled with dynamic approach as expected. It is also realized that the distribution systems comprise several sub-systems as what referred in introduction, so to provide any delivery service would involve those sub-systems

## 2.2. Dynamic Simulation for Logistics Model

To be more specific with the proposed logistics model Figure 2 illustrates possible implication for which the distribution systems explained in Figure 1 exists. Figure 2 clearly denotes the interrelation among the logistic components (e.g., orders received, inventory, shipment, and their possible adjustments), wherein the causal loop may further indicate the balance, and hence arrow adjusts its feedback with

opposing or supporting manners. More comprehensive discussion on the system dynamics can be found in Forrester [1969, 1971].

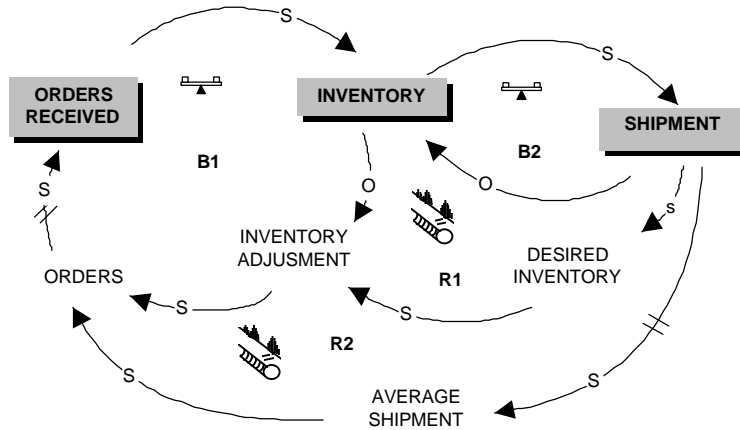


Figure 2: Causal Loop Diagram for Logistics Model

Having the causal loop as represented in Figure 2, any simulation can be made for certain resources or strategies of expected situation. What should be emphasized further in the analysis is that accuracy may not be performed very well rather than indicating the trends of impacts. This is the aim of the research to propose a tool to logistic business manager to formulate best policy or strategy satisfying producer and consumer at all time. Next section discusses the logistics model development and its sub-system simulation.

### 3. Model Development

As a mathematical programming the proposed logistics model is determined to maximize the revenue of sales subject to its limited resources, and such programming can be written as;

$$\text{Max } Z[Q] = \sum_i \dot{a}_i Q_i(t_n) \cdot U_i \quad \dots\dots (1)$$

Subject to,

$$\dot{a}_i Q_i(t_n) \leq Q_{CAP} \quad \dots\dots (2)$$

$$\dot{a}_a R_a(t_n) = Q_i(t_n) \quad " \quad a, i, n \quad \dots\dots (3)$$

$$t_1 < t_2 < t_3 < t_4 \dots\dots < t_N = T \quad \dots\dots (4)$$

With state of dynamics, for order fulfillment, as

$$Q_i(t_n) = Q_i(t_{n-1}) + \mathbf{D}Q_i(t_{n-1}) \quad " \quad i, n \quad \dots\dots (5)$$

Where;

$Q_i(t_n)$  = quantity of commodity ordered at region  $i$  at instant  $t_n$

$U_i$  = unit price of commodity at region  $i$

$Q_{CAP}$  = maximum production quantity

$R_a(t_n)$  = raw material  $a$  that composes the commodity  $Q$  at instant  $t_n$

$t_N = T = N$ th discrete time or end of time period

Besides the model derived in equations (1) – (5), the other significant underlying assumption is that the delivery has unlimited capacity of fleet. It is also worth noting that quantity to be fulfilled in instant ( $t_n$ ), ( $t_{n-1}$ ) plus the quantity ordered in time ( $t_n$ ) slice determined. The model is linear in general, however the solution form is not closed because it deals with time dependency. Further discussion on linearity can be found in de Neufville [1990].

The followings are the sub-models developed for each level of logistic process that would simulate performance of model (1) to (5) based on certain availability of resources.

### 3.1. Raw Material Stock Sub-Model

This sub-model is responsible with the availability of raw materials to compose the produced commodity. Figure 3 illustrates the sub-model of raw material stock in the form of dynamic simulation. In this sub-model the stock is determined by both inflow (e.g., absorbed) and outflow (e.g., expired and used) materials, which are further decided by their composition.

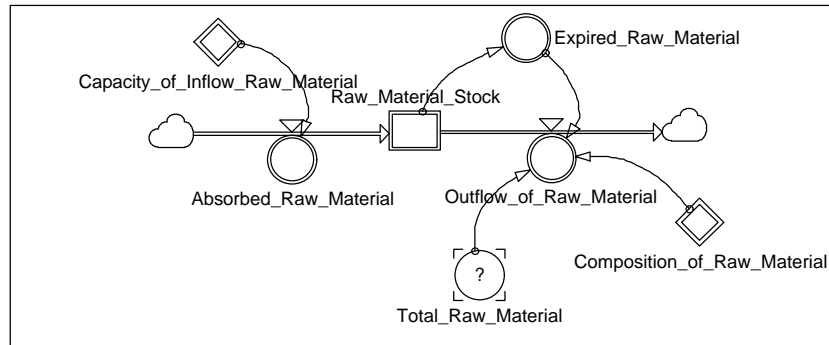


Figure 3: Raw Material Stock Sub-Model

### 3.2. Production Process Sub-Model

This sub-model is responsible in the production process in wherein various raw materials are composed to produce the intended quantity and quality of commodity. In this particular research a single commodity is assumed with a fixed production capacity. Furthermore, Figure 4 illustrates the dynamic simulation model for the production process. The net production in the process is somehow

determined by its gross production, net factor, raw material availability, and fabrication capacity of production machines/tools.

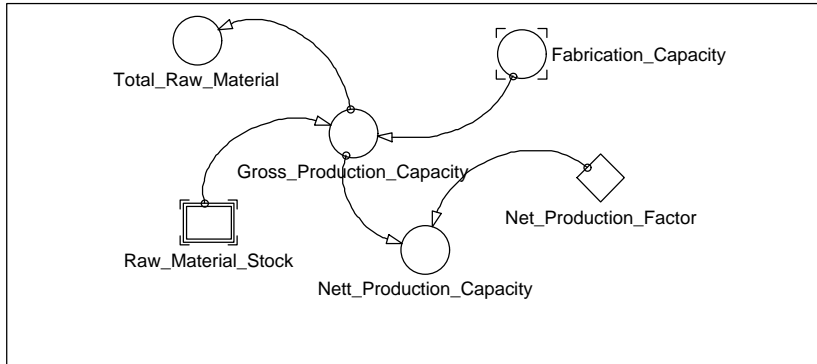


Figure 4: Production Process Sub-Model

### 3.3. Production Stock Sub-Model

As a buffer for distribution a logistic system may require a stock for production as results of manufacturing, assembling or else. This may not necessarily be available rather dependent upon the nature of produced commodity. However for the completeness of logistics model, a production stock model is provided and illustrated in Figure 5.

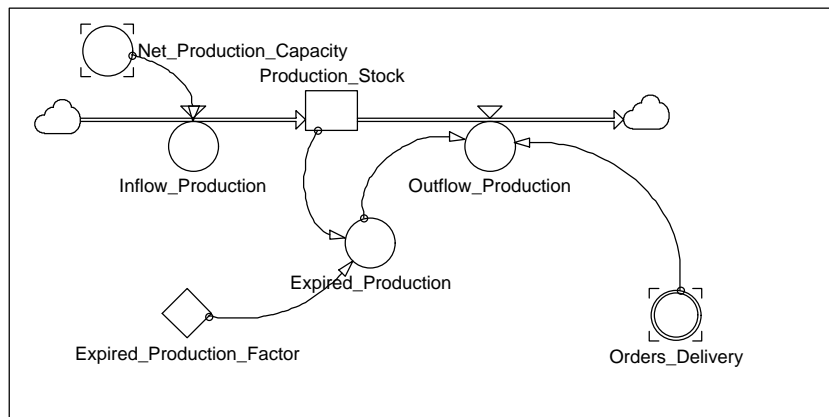


Figure 5: Production Stock Sub-Model

It can be seen in Figure 5 that production stock is determined by both inflow and outflow production, which is further described by the orders delivered and expired production. As for the inflow production, its magnitude can be simply derived from the net production capacity. And similar case can be made for the expired production, which is influenced by the expired production factor.

### 3.4. Customer Order Sub-Model

This sub-model is responsible in managing the orders of customers. This part may come up quite complex since quantity of orders are used to exceed the production capacity, so delay of deliveries is inevitably. This sub-model is in charge to decide the customers to be satisfied and their priority, and how best unsatisfied customers be treated, would be coordinated with production process as well as distribution capacity. Figure 6 illustrates briefly the customer order sub-model.

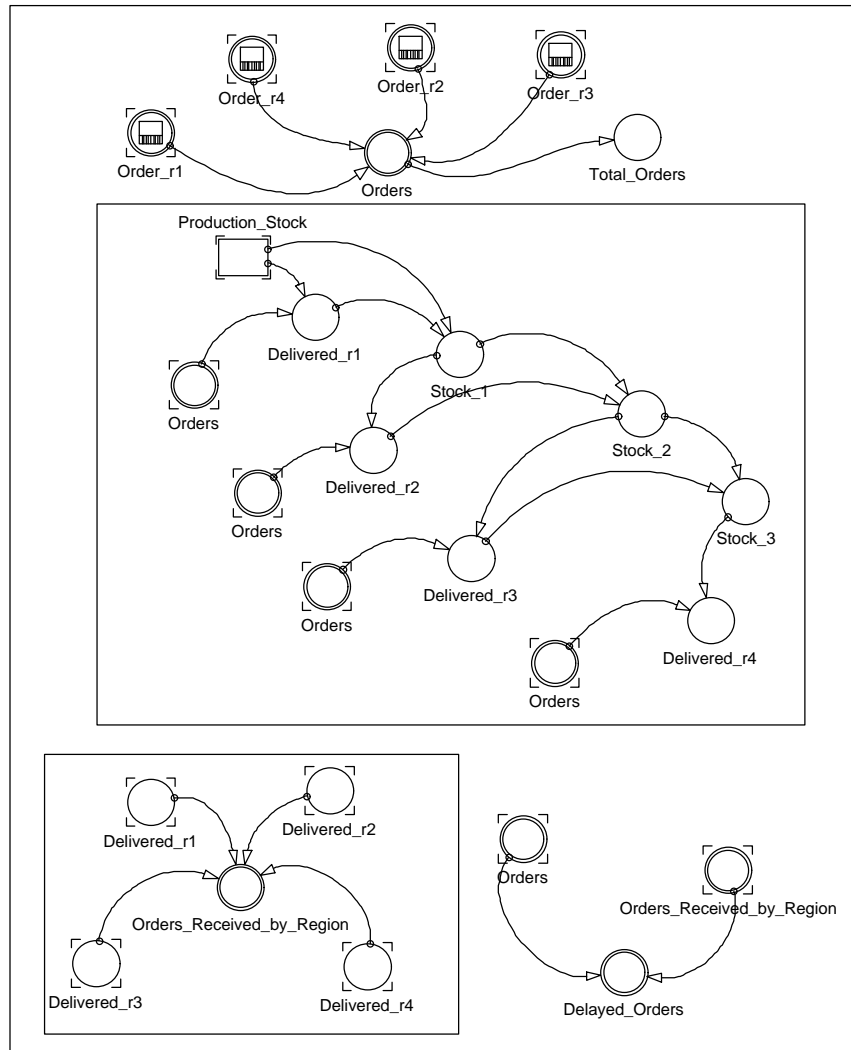


Figure 6: Customer Order Sub-Model

In this particular model number of regions is limited to four, although in the large-scale model this number is flexibly higher. It can be expected too within the model that delayed delivery could be handled I the following delivery for the same region.

### 3.5. Distribution Sub-Model

This last sub-model is responsible in managing strategies of delivery to the customers within certain limited resources such as fleet, production quantity and so forth. Furthermore Figure 7 illustrates the sub-model.

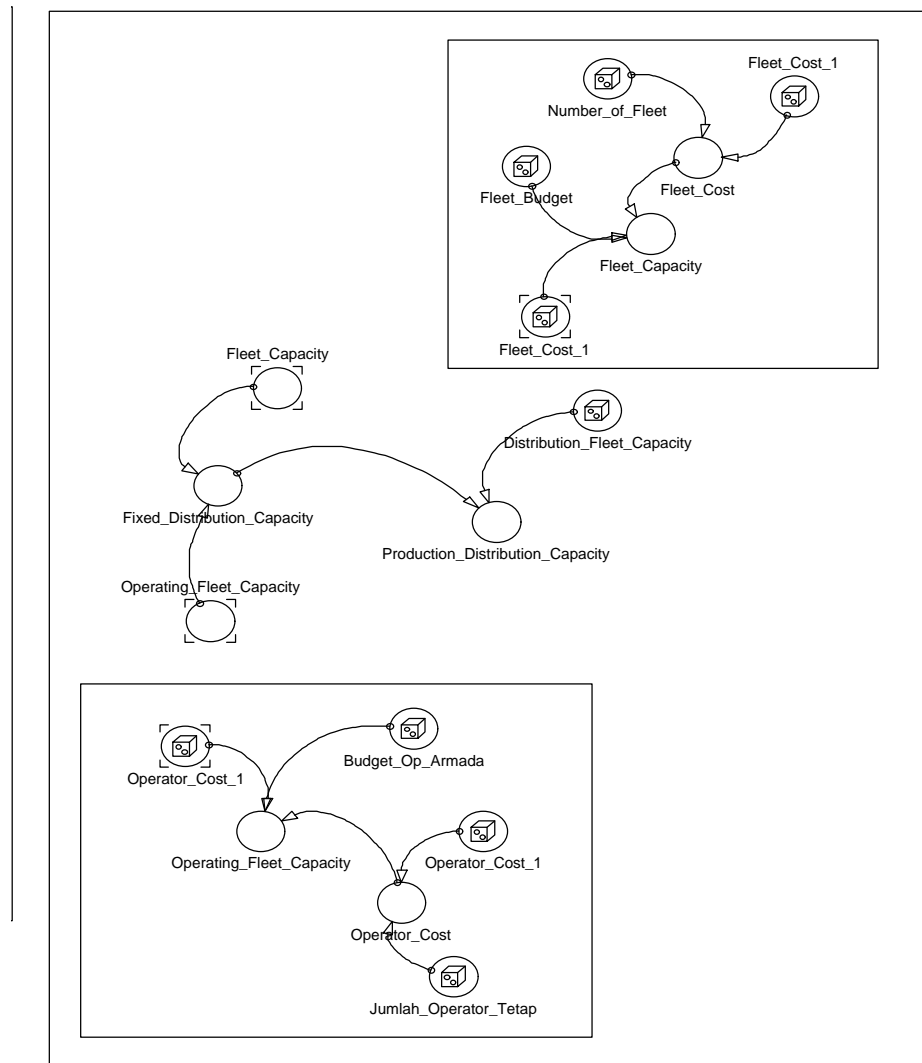


Figure 7: Distribution Sub-Model



In this distribution model it is explained that its capacity is determined with product and fleet availability. Furthermore, the distribution cost would in some extent derive the sale price as composed by transport and production costs.

#### 4. Some Simulation Results

In order to comprehend the performance of the model a case is made for some production and distribution capacities along with the availability of raw materials. Suppose a cement factory with the following quantity and cost components (i.e., some are following pseudo random variables and normal distribution);

Budget allocation for machine, human resource, and fleet are 100, 4, 120 million Rp respectively (e.g., Rp is the Indonesian currency). Costs spent for machine, human resource, owned fleet, rent fleet respectively are 10,000,000, 20,000, 85,000, 400,000 Rp. Number of machines, human, fleet, and operators are 20, 200, 400, and 800 respectively. Production capacity per day for each of machine, human and fleet are 1,200, 100, and 15 tons/day respectively. While for delivery region 1,2,3,and 4 have the following distance 30, 80, 400, 2000 kms, and can be delivered in expectedly 3, 4, 6, and 6 days respectively. Finally their potential order for each region is recorded as 40,000, 40,000, 40,000 and 30,000 tons/day respectively.

In this case a strategic delivery of high utilization rate of fleet is exposed, in which it may mean that priority of delivery is given to the nearest distance of regions. So the nearer the region the higher the priority is. To evaluate impacts of such strategy expected orders from region to region [*pesanan* (1)-(4)] were simulated by time of days as shown in Figure 8.

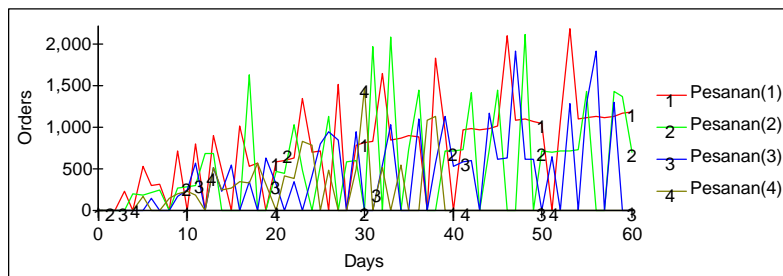


Figure 8: Expected Orders from Regions by Days

Such expected demands or orders might affect total production stock and delivered order as could be reflected in Figure 9. Eventually, how far chosen strategy may satisfy the customers can be reflected by the expected recovery or fulfillment of delayed orders in the ensuing days. To conclude such strategy performance Figure 10 represents the delayed order recovery [*pemenuhan tunda* – (1)-(4)] by region by days.

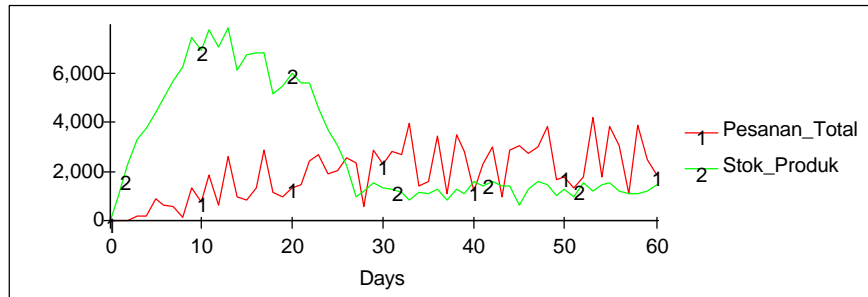


Figure 9: The Expected Total Production Stock & Delivered Orders by Days

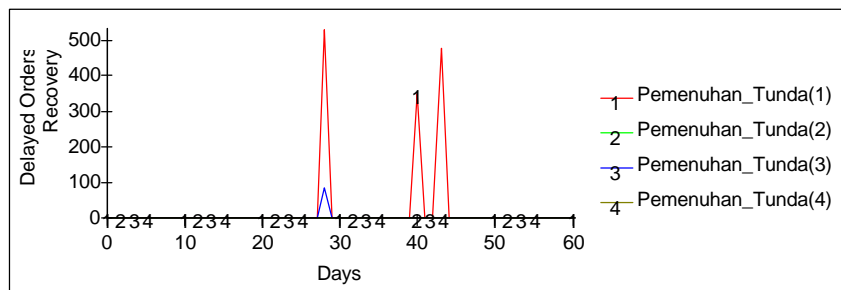


Figure 10: Delayed Orders Recovery by Region by Days

## 5. Conclusions

A comprehensive logistics model based on dynamic simulation is proposed in this research. The model is formulated in mathematical programming with objective function of maximizing the sales revenue subject to various operational constraints. And five sub-models (e.g., raw material stock, production process, production stock, customer order, and distribution) are developed to solve the formulated logistics model. To comprehend the performance of model, a case is made and various outcomes of simulation are discussed. Eventually, it is expected that the model could be enhanced for larger scale and higher complexities to deal with some operational parameters of *good* logistic systems.

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