# Serialized Optimization of Supply Chain Model Using Genetic Algorithm and Geometric Predictions

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***Abstract***- *The operation of all commerce for a product is defined almost entirely by its individual supply chain, such that any improvements made upon the process reflects directly upon the product metadata. The supply chain in turn, can be optimized in a variety of ways ranging from technical specifications to micro-management changes.*

*In this paper we attempt to address the resource allocation management – part of the supply chain –of a sample product using geometric mean to predict, and value permutation genetic algorithm to optimize the resource division process for the provided supply chain in an endeavor to surpass interdisciplinary boundaries by unravelling an industrial engineering issue by employing traditional software techniques.*

***Keywords***- Genetic Algorithm, Geometric Mean, Interdisciplinary Project, Optimization, Resource Management, Supply Chain.

## I. INTRODUCTION

Today's environment expects an integration of many technologies to generate results that are required by a user of the system. These results may require a versatile combination of various techniques and workarounds to achieve the designated goals. A product development methodology is a necessity in most situations where mankind is involved. This need arises due to the socio-economic strata that ultimately manifest themselves in the form of project being a success or yet another failure in a highly competitive commerce scene. All such projects involve products – be they material goods or otherwise – that flow between the creator and the consumer in a closed loop; the obtuse linear progression of all business is thereby called a supply chain.

The supply chain involved in any product or business defines the gross total of profits or losses incurred in the process. This process will be augmented by the addition of complex genetic algorithms that will process the process to present optimal parameters for every individual supply chain. This means that for every product involved in the optimization, an ideal supply chain would likely be developed without heavy investment of manpower, thus computerizing the related work.This is an interdisciplinary project which encounters a mechanical problem to be solved by software techniques. The expected results theoretically surpass those achieved by conventional mechanical methods.

A. Supply chain resilience is defined as" the ability of a supply chain to cope with change", is regarded as the next phase in the evolution of traditional, place-centric enterprise structures to highly virtualized, customer-centric structures that enable people to work anytime, anywhere. Resilient supply networks should align its strategy and operations to adapt to risk that affects its capacities. There are 4 levels of supply chain resilience. First is reactive supply chain management. Second is internal supply chain integration with planned buffers. Then comes collaboration across extended supply chain networks. Finally is a dynamic supply chain adaptation and flexibility.

It is not about responding to a one-time crisis, or just having a flexible supply chain. It is about continuously anticipating and adjusting to discontinuities that can permanently impair the value preposition of a core business with special focus on delivering ultimate customer centricity. Strategic resilience, therefore, requires continuous innovation with respect to product structures, processes, but also corporate behavior. Recent research suggests that supply chains can also contribute to firm resilience.

With increasing globalization and easier access to alternative products in today's markets, the importance of product design to generating demand is more significant than ever. In addition, as supply, and therefore competition, among companies for the limited market demand increases and as pricing and other marketing elements become less distinguishing factors, product design likewise plays a different role by providing attractive features to generate demand. In this context, demand generation is used to define how attractive a product design is in terms of creating demand. In other words, it is the ability of a product's design to generate demand by satisfying customer expectations. But product design affects not only demand generation but also manufacturing processes, cost, quality, and lead time. The product design affects the associated supply chain and its requirements directly, including manufacturing, transportation, quality, quantity, production schedule, material selection, production technologies, production policies, regulations, and laws. Broadly, the success of the supply chain depends on the product design and the capabilities of the supply chain, but the reverse is also true: the success of the product depends on the supply chain that produces it.Since the product design dictates multiple requirements on the supply chain, as mentioned previously, then once a product design is completed, it drives the structure of the supply chain, limiting the flexibility of engineers to generate and evaluate different (and potentially more cost-effective) supply chain alternatives.

If all relevant information is accessible to any relevant company, every company in the supply chain has the ability to help optimize the entire supply chain rather than to sub-optimize based on a local interest. This will lead to better-planned overall production and distribution, which can cut costs and give a more attractive final product, leading to better sales and better overall results for the companies involved. This is one form of Vertical integration.

Incorporating SCM successfully leads to a new kind of competition on the global market, where competition is no longer of the company-versus-company form but rather takes on a supply-chain-versus-supply-chain form. The term "logistics" applies to activities within one company or organization involving product distribution, whereas "supply chain" additionally encompasses manufacturing and procurement, and therefore has a much broader focus as it involves multiple enterprises (including suppliers, manufacturers, and retailers) working together to meet a customer need for a product or service.

Reverse logistics is for all operations related to the reuse of products and materials. It is "the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics." Growing green concerns and advancement of green supply chain management concepts and practices make it all the more relevant. The reverse logistics process includes the management and the sale of surplus as well as returned equipment and machines from the hardware leasing business. Normally, logistics deal with events that bring the product towards the customer. In the case of reverse logistics, the resource goes at least one step back in the supply chain.

A genetic algorithm (GA) is a meta heuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms (EA). Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection. Genetic algorithms do not scale well with complexity. That is, where the number of elements which are exposed to mutation is large there is often an exponential increase in search space size. This makes it extremely difficult to use the technique on problems such as designing an engine, a house or plane. In order to make such problems tractable to evolutionary search, they must be broken down into the simplest representation possible. The second problem of complexity is the issue of how to protect parts that have evolved to represent good solutions from further destructive mutation, particularly when their fitness assessment requires them to combine well with other parts. The "better" solution is only in comparison to other solutions. As a result, the stop criterion is not clear in every problem. An expansion of the Genetic Algorithm accessible problem domain can be obtained through more complex encoding of the solution pools by concatenating several types of heterogeneously encoded genes into one chromosome. This particular approach allows for solving optimization problems that require vastly disparate definition domains for the problem parameters.

## II. LITERATURE REVIEW

The premise for the project is taken from [1]. It presents a mathematical model for integrated evaluation of green design and green manufacturing processes. The supply chain is visited in [2] This paper includes detailed expert reviews on supply chain resilience and its importance in the modern business scape and [3] where the principles of resilience in any organization or setup is discussed and its management resources are obtained from [4] where optimization occurs in a loop in which a backwards traversal of the supply chain is the second half of the process and is known as reverse logistics for the process. These present the value of including reverse logistics fundamentally into a supply chain and how it affects the management of the entire setup.

Its relevance to the optimization process is found in [5] which pertains directly to the optimization process and the idea to port mechanical processes to a different landscape to resolve inherent issues stems from the proposals presented here. The concepts of forward and reverse logistics are taken from [6] and [7]which discuss the concept of supply chains and their functionality in any product development process.

Genetic Algorithms are explored in [8]where the process involved in modelling a problem to be solved by a GA as well as the inherent issues involved in the use of genetic algorithms and their principles and execution. Finally, the idea of Green Design and Manufacturing is implemented in [9], [10]and[11] that explore many available venues that can be built upon to enhance the product process in eco-friendly and often profitable manners.

## III. METHODOLOGY

### A. System Architecture

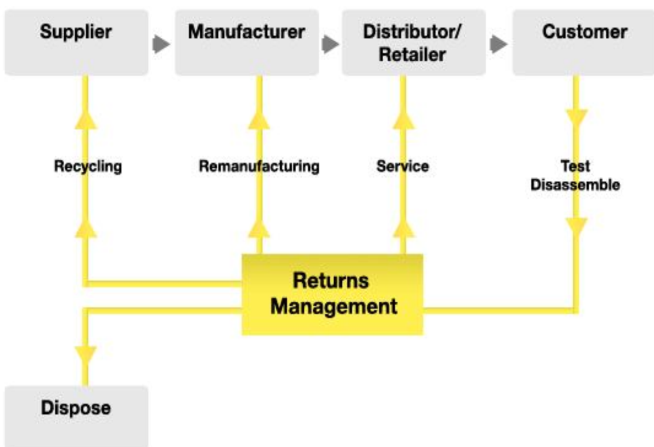


Fig: Supply Chain with Reverse Logistics

The above model represents the basis for the operation of our algorithm. The process starts from the supplier issuing the product of the supply chain to the manufacturer to be produced in bulk from where the product spreads to various distribution clusters that service the final customer. This goes backward in the form of returns and lack of product demand thus forming the complete supply loop. The project targets these key points in the commerce flow to benefit the user by generating data pertinent to the product.

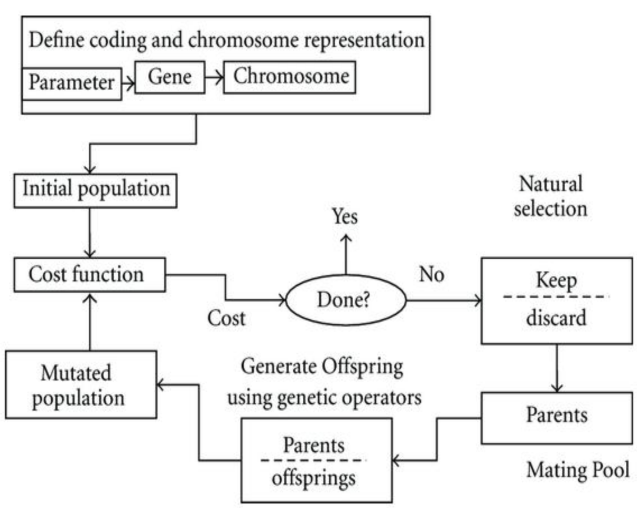


Fig: Genetic Algorithms

To make raw available data on the product into concrete deductions for the expected results theorized, the supply chain model is reshaped into multiple parts that are each then optimized and then put together for a reasonably improved result. The parts each have parameters that contribute to the chromosome pool that's used by the program to generate newer and hypothetically improved specimens that are then added to the new pool. This process is repeated until a certain improvement is achieved or a number of generations have been bred for the purpose of outputting the most optimal available deductions on the characteristics of the parameters in the problem, the supply loop.

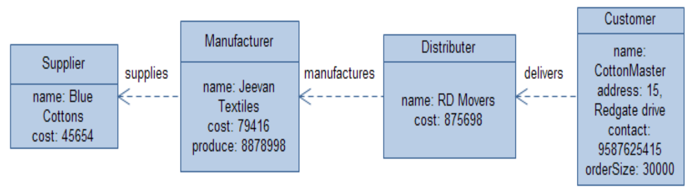


Fig: Supply Chain Sample Representation

The above diagram depicts the supply chain dependencies for a real world example. In a supply chain, materials flow forward while information flows backward to enable a perpetual evolution in the process.

Below, the individual classes that constitute the supply chain are each depicted as a composite figure of further classes and objects. This is usually the magnification involved in the working of non-linear transactions, i.e. say the owner of a cotton farming business is the supplier of cotton – which is the raw material – for the supply chain and in turn employs workers (like cotton foragers and such) to do the harvesting and other involved work.

### A. UML Design

We have used unified modelling language diagrams to clarify our case and simplified the example visualization, simultaneously.

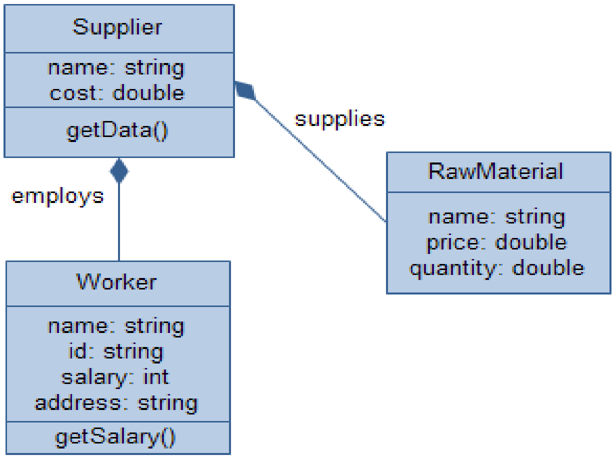


Fig: Supplier Class

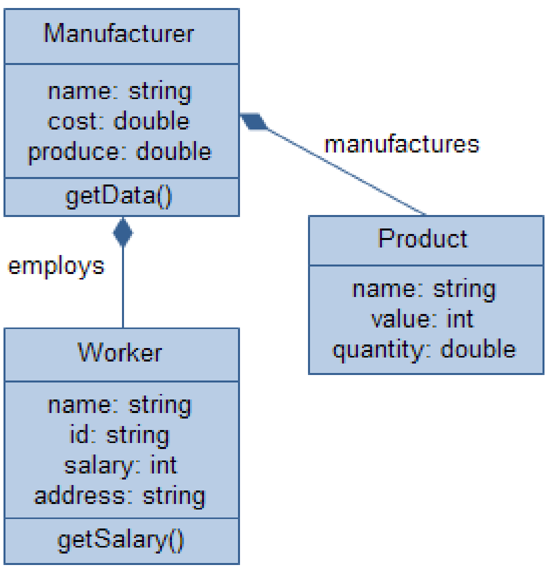


Fig: Manufacturer class

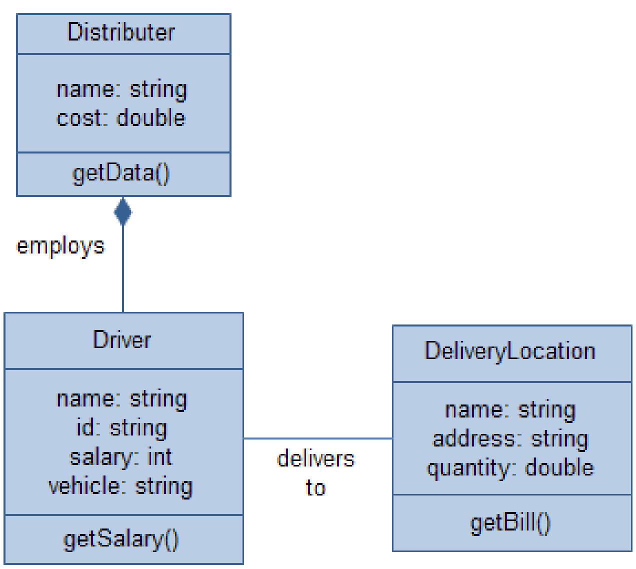


Fig: Distributer class

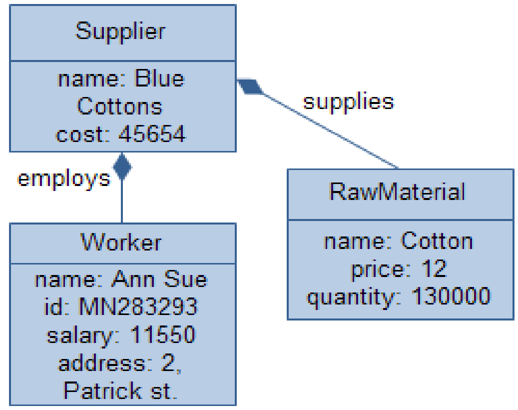


Fig: Supplier Object

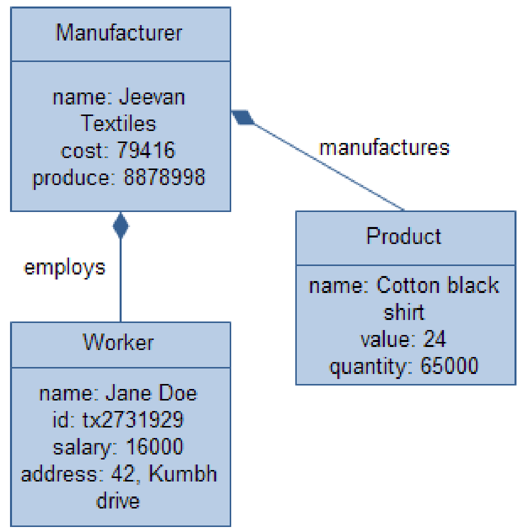


Fig: Manufacturer Object

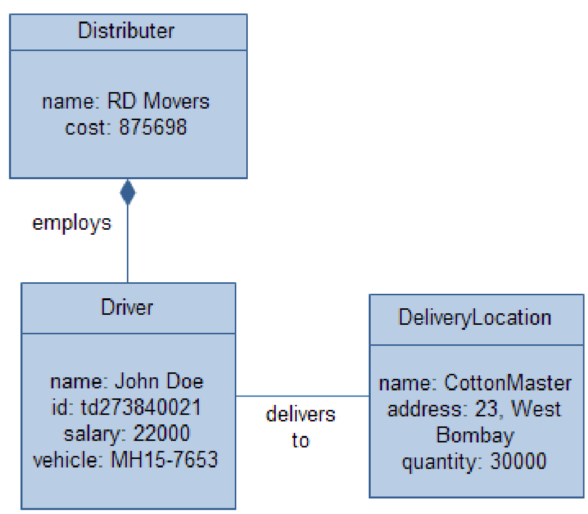


Fig: Distributer Object

Shown above are the instantiated form of the base classes involved in the example. This aids in learning and implementing the problem model at a greater depth.

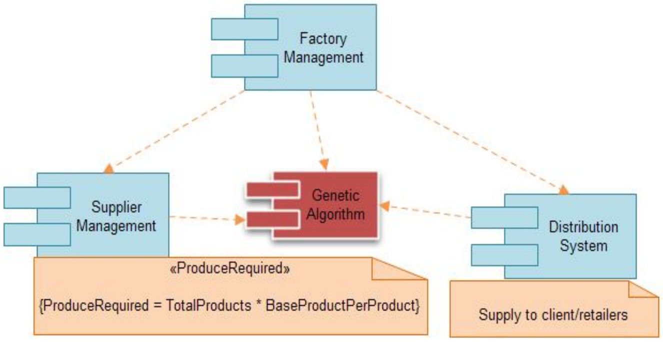


Fig: Component Diagram

The different components involved in the chain react to and depend upon each other as well as the control systems (here, the Genetic Algorithm) to function expectedly.

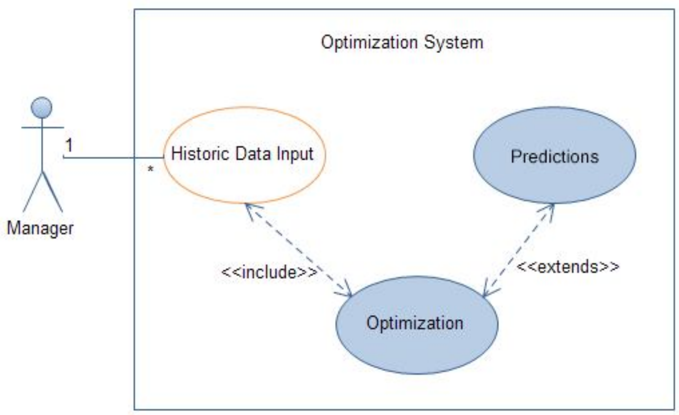


Fig: Use Case Diagram

Every mechanical model is directly or indirectly reacting to the inputs provided by the user. A use case diagram depicts this understanding between man and machine. Here, we input the historical data that is used to predict the target sales for the succeeding term which in turn is used to approximate the resource allocation.

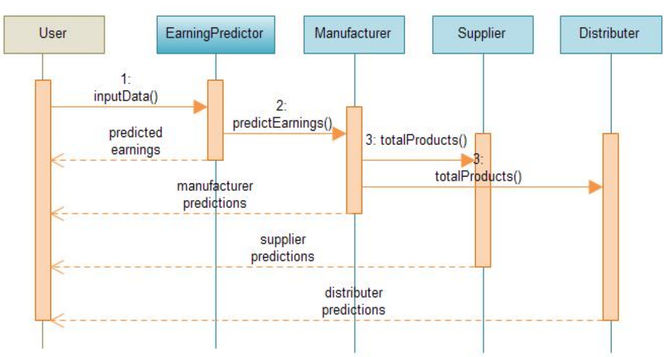


Fig: Interaction/Sequence Diagram

The sequence diagram shows the complete flow of all data and commands possible in the system and as such is a necessary tool for almost every project design.

### B. Mathematical Model

<u>Step 1</u>: Geometric Prediction of Target earnings.

To obtain the most probable earning for the next business term for the algorithm, historical data of the past earnings is analyzed and the growth rate is calculated through a series of equations to generate the mathematical mean for the available data. Say,

LT =Last term earnings

LG = Last Growth rate i.e. $\{\frac{LT}{Earning\ preceding\ LT}\}$

MTG = Geometric mean of Total Growth rate

Then,

$$Target\ (Predicted)\ Earning = LT * \{\frac{LG + MTG}{2}\}$$

<u>Step 2:</u> Using a Genetic Algorithm to predict metadata for Manufacturer.

We start with the middle of the supply chain in order to identify the quantity of processed final products required to satisfy the Target (Predicted) Earnings. We take as the demonstration product, an arbitrary company that produces clothing wear, specifically blue cotton shirts. Thus, we are going to optimize the supply chain for said blue cotton shirts. Here, we assume that the company handles raw material supply, manufacturing and delivery of the products to either retailers or other clientele. Hence, regarding the process of manufacturing of said blue shirts, say,

E1 = Employee or Factory worker (assuming rate of shirt making per person to be unity)

M1 = Machines or equipment utilized (assuming rate of shirt making per person to be unity)

T1 = Time taken to meet the production criteria/goal e.g. in days

BP = Base price of one completed, processed product

ES1 = Salary of E1

EM1 = Operation cost of M1

Then,

$$Target\ Earning = T1 * [E1 * \{(M1 * BP) - ES1\} - (M1 * EM1)]$$

where Target Earning is calculated in Step 1.

This modelling allows us to apply GA – to the above equation – to predict the optimal assignment values for E1, M1 and T1, i.e. the manpower required in proportion to the machines operated for the obtained time period to gain the Target Earnings, after employee and tools cost deduction.

Step 3: Using a Genetic Algorithm to predict metadata for Supplier.

Now, in the previous step, we can observe that the product of the employees recruited, machines operated and time allotted grants us the total number of finished, processed product (the blue cotton shirts) such that,

TP = Quantity of finished products generated
Then,

$$TP = E1 * M1 * T1$$

So by virtue of this rationale, if say,
E2 = Employee or Cotton Picker (assuming rate of cotton collection per person to be unity)
RP = Units of raw materials e.g. cotton, required to generate one unit of final product
T2 = Time taken to meet the supply criteria/goal e.g. in days
Then,

$$TP * RP = E2 * T2$$

This modelling allows us to apply GA – to the above equation – to predict the optimal assignment values for E2 &T2, i.e. the manpower required for the specified time to generate the required amount of raw materials i.e. cotton.
We can also obtain the *cost for raw material supply* if a unit price of the raw material is known.

Step 4: Using a Genetic Algorithm to predict metadata for Distributer.

Employing a logically congruent rationale to the previous step, we attempt to arrive at the optimal assignments for the final phase of the supply chain as concerns the company producing blue cotton shirts. Say,

E3 = Employee or Delivery truck driver
T3 = Time taken to deliver the produced goods to the consumer e.g. in days
Then,

$$TP = E3 * T3$$

And again like the previous steps, a convergent GA is used to find the best identifiable values for E3 & T3 i.e. time taken by the truck drivers to deliver the finished products generated in the factory.

We can also obtain the *total delivery cost* if we know the hiring costs for the truck drivers for a unit time.

NOTE1: T1, T2 and T3 can have the same random maxima for simplicity's sake.

NOTE2: As the implementation and general nuances of Genetic Algorithms are widely known and expounded upon for decades by a host of very skilled and specialized personnel, we see fit to exclude those replications from this paper, both in an effort to present newer findings and avoid direct plagiarism of better works.

## IV. RESULTS

### A. Findings

| Financial Term | January | February | March | April | May | June (predicted) |
|---|---|---|---|---|---|---|
| Income (in unit thousands) | 340 | 372 | 390 | 441 | 415 | 413.34 |
| Last Growth Rate | n.a. | 1.094 | 1.048 | 1.131 | 0.941 | |
| Total Growth Rate | n.a. | 1.094 | 1.071 | 1.09 | 1.051 | |
| E1 (salary 350 units) | | | | | | 9 |
| M1 (cost 800 units) | | | | | | 4 |
| Base Product Price (in units) | n.a. | n.a. | n.a. | n.a. | n.a. | 750.472 |
| T1 (in days) | | | | | | 20 |
| E2 | | | | | | 30 |
| Raw items/product | n.a. | n.a. | n.a. | n.a. | n.a. | 0.25 |
| T2 (in days) | | | | | | 6 |
| E3 | | | | | | 9 |
| Vehicle product capacity | | | | | | 20 |
| T3 (in days) | | | | | | 4 |

The algorithm will give us the optimal or most convergent metadata for the parameters available for the supply chain.

Thus, if we know the earnings from previous terms, employee salaries and equipment maintenance costs, our product price, raw materials required to make one blue cotton shirt and the carrying capacity of the delivery trucks, we can accurately predict the employees to be hired, the machines to be operated, the time taken for each echelonas well as the costs incurred at each link of the supply chain e.g. If a truck driver is paid 400 units for working 1 day, then the total delivery/shipment costs are $14{,}400\ (9 * 4 * 400)$.

**B. Advantages**

- Greater supply chain profits.
- Selective optimization of processes.
- Optimal tweaking of resource allocation.
- Increased reliability of supply chain.

## V. CONCLUSION

Thus, we see that mechanical or hardcore industry issues can indeed be resolved successfully and efficiently through software design and development techniques. This is in an effort to bridge the skill requirement gap between the mainstream trades such that future generations can involve themselves in either aspect and migrate between them with relative ease. In doing so we ensure that a greater boom in hidden talents can be observed as students customize their learning objectives from a humongous variety such that each potential combination offers equally favorable opportunities as the rest. This is hopefully among the many efforts that cumulatively usher a better tomorrow.

We understand that like the industry resource allocation optimization issue presented in this paper, there exists a very large list of problems or synchronization-errors that obstruct attempts at technological advancements and any of them can be an excellent basis for an extension on the proposed concepts, provided that the right questions are asked and the design model is apt. We heartily encourage all such endeavors and would gladly aid – in our capacity – any who require our foresight for their work, now or in the future, provided that they ask.

## ACKNOWLEDGMENT

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