Collaborative Manufacturing Platform

A PROJECT REPORT

Submitted in partial fulfilment of the

requirements for the award of the degrees

of

BACHELOR OF TECHNOLOGY

In

MECHANICAL ENGINEERING

Submitted by:

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Guided by:

Dr. Bhupesh Kumar Lad

INDIAN INSTITUTE OF TECHNOLOGY INDORE

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CANDIDATE'S DECLARATION

We hereby declare that the project entitled '**Collaborative Manufacturing Platform'** submitted in partial fulfilment for the award of the degree of Bachelor of Technology in Mechanical Engineering completed under the supervision of **Dr. Bhupesh Kumar Lad**, Assistant Professor, Mechanical Engineering, IIT Indore in an authentic work.

Further, I/we declare that I/we have not submitted this work for the award of any other degree elsewhere.

Anshul Singh Jadone **Anuj Agarwal**

Certificate by BTP Guide(s)

It is certified that the above statement made by the students is correct to the best of our knowledge.

Dr. Bhupesh Kumar Lad

Assistant Professor,

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Preface

This report is on “Collaborative Manufacturing Platform” is prepared under the guidance of **Dr. Bhupesh Kumar Lad.**

Through this report we have tried to present a collaborative system

We have tried to the best of our abilities and knowledge to explain the content in a lucid manner.

Anshul Singh Jadone and Anuj Agarwal,
B.Tech. IV Year,
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Acknowledgements

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Without their support this report would not have been possible.

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Abstract

Today, advancements in technology are taking place exponentially. With the rise of Internet of Things (IoT), the application of computer technology is becoming ubiquitous. Considering the area of manufacturing, machines and industries are becoming smarter. However, considering the bigger picture, as the society is now thriving for mass-customization, in this work we propose an operation management system which will enable industries to achieve the goal of “mass-production with mass-customization” which is the next challenge for the industry. Thus, we devise a platform, termed as **Collaborative Manufacturing Platform**, which will make the above notion possible. It will interconnect and hence enable interaction between the pillars of manufacturing viz. suppliers, co-industries, customers and the industry leading to enhanced profits and efficient decision-making.

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1. Introduction

Today, advancements in technology are taking place exponentially. With the rise of Internet of Things (IoT), the application of computer technology is becoming ubiquitous. Considering the area of manufacturing, machines and industries are becoming smarter, and are witnessing the advert of what is said to be the *Fourth Industrial Revolution.* Cyber-Physical Systems (CPS), data analytics and computer optimization are the main drivers of this change.

The manufacturing industry is leading in the Internet of Things for various reasons: some are historical, others are related with the so-called next industrial revolution (Industry 4.0) and then there are the many uses cases and actual IoT deployments that offer rapid return and enable manufacturers to realize digital transformations from several perspectives: efficiency, automation, customer-centricity, competitive benefits and the advantages which are offered by using data across the manufacturing value chain and to tap into new revenue sources, a key aspect of digital transformation in manufacturing.

To visualize the usage of the Internet of Things in manufacturing with an overview of the various mentioned places/contexts where IoT is leveraged in the manufacturing space, the graphic below from Microsoft offers a great overview.

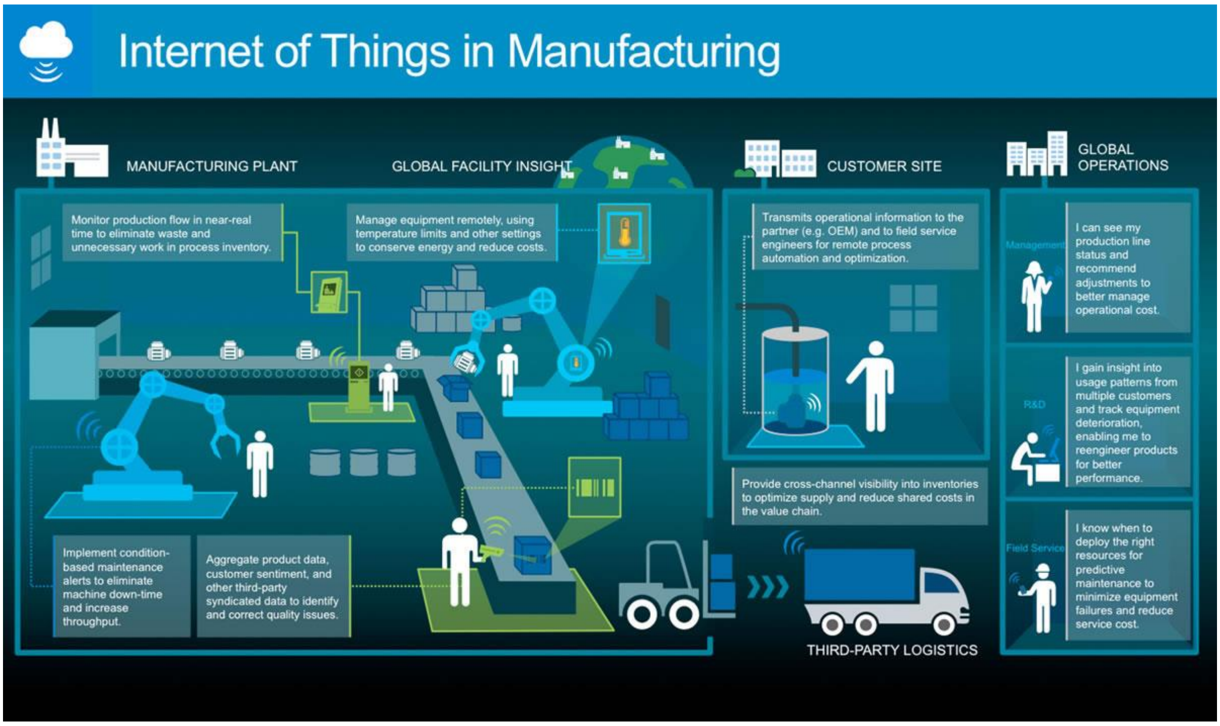


Fig. 1. Internet of Things in manufacturing – the Microsoft view

It also shows some additional or, let's say, more detailed use cases and the benefits they offer, including:

- Production flow monitoring: optimize flow, eliminate waste and avoid unnecessary work in process inventory.
- Remote equipment management, including setting specific limits and parameters to save energy and costs.
- Condition-based maintenance alerts: optimize machine availability, minimize interruption and increase throughput.
- An important one: the usage of various data (product, customer sentiment and more) as a driver of quality monitoring and enhancement in function of outcomes and this aggregated data.

IoT is transforming the way organizations in different industries are doing business including the manufacturing companies. Till now technology has been used primarily for running the business and managing manufacturing operations, for automating processes and for collecting data related to assembly jobs. However, IoT goes well beyond this to next level for data collection.

Since its birth two centuries ago, the manufacturing industry has evolved through several paradigms. The first paradigm was "**Craft Production**", which created the product the customer requested but at a high cost. There were no manufacturing systems associated with this paradigm. In addition, the providers of craft products were confined to localized geographical regions hence such production was not scalable. Interchangeability and the moving assembly lines enabled the development of "**Mass Production**" which provided low-cost products through large scale manufacturing. However, the number of varieties offered by such production was very limited. In the late 1980s, global competition and consumer demands for high product variety led to the development of "**Mass Customization"**. Manufacturers designed the basic product architecture and options while customers are allowed to select the assembly combination that they prefer most.

What is the next manufacturing paradigm?

Mass Production along with Mass Customization → *Manufacturing by Mass*

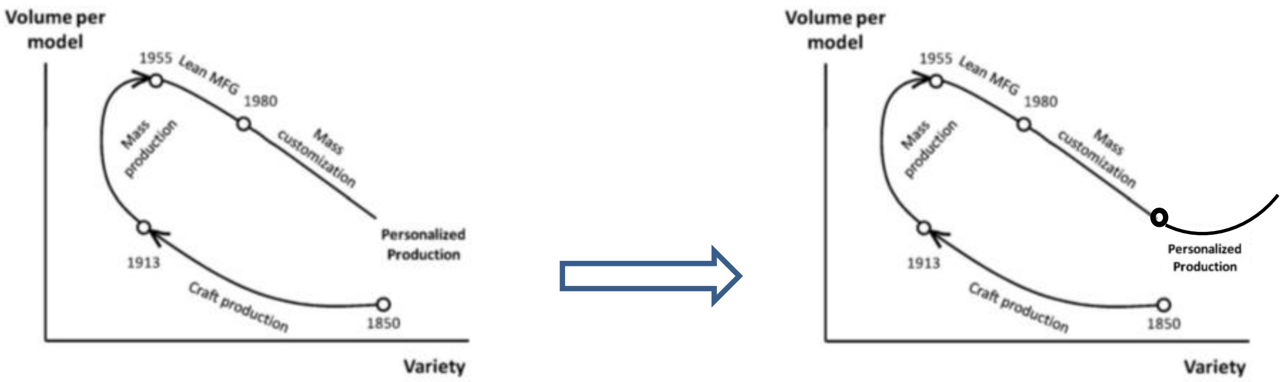


Fig. 2. Volume variety relationship in manufacturing paradigms and the next paradigm

This project is an effort towards realizing such a future in manufacturing. Thus an operation management system is proposed which will enable industries to achieving the goal of "mass-production with mass-customization" which is the next challenge for the industry. Thus, we devise a platform which will make the above notion possible. It will interconnect and hence enable interaction between the pillars of manufacturing viz. suppliers, co-industries, customers and the parent industry. It is a system that when plugged into the operation, offers a complete real-time and remote planning, monitoring and decision making solution. The project considers a narrow set of assets, factors and parameters that can be extended easily according to the needs.

Structuring major segments in the collaborative system and contemplating factors was the major challenge faced. Each segment further involved further categorization and demanded deep study of the factors imparts influence on the system. Cost-models and selection algorithms that involve multiple factors get exponentially complicated with increase in parameters. Dynamic re-modelling and real-time tracing was a key task in this area. Concept of resource sharing was also included in the model. The model also allows a deep study of dependencies and weighted influence of different factors through simulations. It allows for consideration of complex cases and detailed models, and it makes the project scalable to increase in problem size.

The following benefits are expected of the project:

- A platform enabling full-fledged interaction between the pillars of manufacturing.
- Acquiring an overall increase in profit for the manufactured product.
- Faster, intelligent and more data-driven decision making possible.
- Reduce wastage, downtime and inventory.

Following sectors are the immediate beneficiaries of such a system:

- Small or medium enterprise and large manufacturing industry would be interested in adapting this system to increase the demand of their products and hence the profit.
- Industries that provide customization of their products can produce customized product on a large scale by alluring new customers over the globe interested in buying the same product.
- Customers form the demand pool and the ones involved in this system will be benefited as they can get easy recommendations of the product they want and at a lower comparative cost.
- Suppliers can have a clearer and dynamic tab on the demand of products industries are looking for.
- Other industries would be seeking opportunities to collaborate and expand their business by involving in resource sharing.
- Software industries would be interested in developing the applications and other software module, etc. for proposed system.
- The software can be used to simulate various possible scenarios and for the analysis of dependencies of various factors in collaborative manufacturing.

The remainder to this section consists of the definitions of the terms used in the report.

1.1. Introduction to terms used

Demand: Demand is the consumer's need or desire to own the product or experience the service. It's constrained by the willingness and ability of the consumer to pay for the good or service at the price offered.

Customer: A party that receives or consumes products (goods or services) and has the ability to choose between different products and suppliers.

Supplier: A party that supplies goods or services. A supplier may be distinguished from a contractor or subcontractor, who commonly adds specialized input to deliverables.

Industry: The manufacturing or technically productive enterprises in a particular field, country, region, or economy viewed collectively, or one of these individually.

Availability: Characteristic of a resource that is committable, operable, or usable upon demand to perform its designated or required function. It is the aggregate of the resource's accessibility, reliability, maintainability, serviceability, and sociability.

Quality: In manufacturing, a measure of excellence or a state of being free from defects, deficiencies and significant variations.

Due Date: Date on which a bill of exchange (check, draft, letter of credit, etc.) is payable. No grace period may be allowed on a sight draft (due on presentation) but is allowed for a term draft (due on or before a certain date).

Operating Cost: Cost per unit of a product or service, or the annual cost incurred on a continuous process. Operating costs do not include capital outlays or the costs incurred in design and implementation phases of a new process.

Transportation Cost: The expenses involved in moving products or assets to a different place, which are often passed on to consumers.

2. Literature survey

Increasing fluctuations in demand or unforeseen disruptions have a disturbing impact on logistical key figures of manufacturing companies. Common countermeasures, e.g. the increase of the production capacity by adding new machines, always lead to improvements of single key figures while worsening others simultaneously.

The Timberland Company, the fast-growing New Hampshire-based shoe manufacturer, for example, has developed a sophisticated production-planning system linked to a sales-tracking system that updates demand forecasts.

L.L. Bean, the Maine outdoor-sporting-goods company, has started to use its understanding of uncertainty to drive its inventory-planning decisions.

But most companies still treat the world as if it were predictable. They base production planning on forecasts of demand made far in advance of the selling season to provide ample time for efficient production and distribution. And when that approach results in shortages of some products, and in pipelines filled with obsolete components and finished goods because anticipated hot sellers have bombed, it is generally seen as a forecasting problem. Everyone unfairly blames the forecasters.

The real problem, though, is that most companies do a poor job of incorporating demand uncertainty into their production-planning processes. They are aware of demand uncertainty when they create a forecast—witness the widespread reliance on safety stocks—but they design their planning processes as if that initial forecast truly represented reality. They do this for two reasons. First, it’s complicated to factor multiple demand scenarios into planning; most companies simply don’t know how to do it. Second, the dramatic increase in demand unpredictability is fairly recent, so most companies haven’t yet changed their planning systems to adapt to it. The result, as shown by the sharp increase in department store markdowns in the past two decades, has been catastrophic. (See the graph “Skyrocketing Markdowns in the Retail Industry.”)

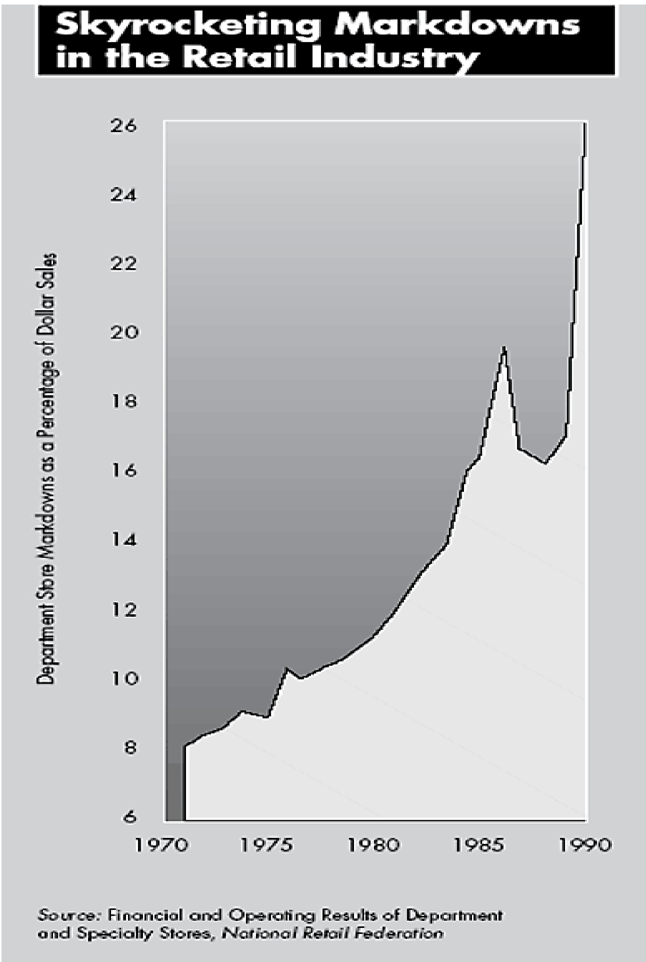


Fig. 3. Skyrocketing Markdowns in the Retail Industry Source: Financial and Operating Results of Department and Specialty Stores, National Retail Federation

General Motors' Cadillac division redesigned its Seville and Eldorado models. Based on initial demand forecasts for its 1992 line, General Motors allocated half the capacity of its Detroit-Hamtramck plant to those two models; the remaining capacity was slated to produce Buicks and Oldsmobiles. However, demand for the Sevilles and Eldorados quickly exceeded supply: GM's underproduction of the two models led to the loss of thousands of potential customers. Scrambling to meet the growing demand, GM changed its allocation and devoted 86% of the plant's capacity to the Cadillac models. Eventually, the company allocated all of the plant's production capacity to the Seville and Eldorado. But the damage had already been done.

In the light of increasing fluctuations in manufacturing, new approaches have to be considered. The utilization of resource sharing for manufacturing companies is the next possible solution in analogy to shared loads in transport logistics. In this context, we refer to production machines as shared resources. Each cooperating company allows others to access its manufacturing resources according to a cooperation agreement. This concept empowers companies to deal with the disturbing events by distributing orders to cooperation partners instead of maintaining safety capacities or redundant systems.

Examples for resource sharing on consumer level can be found, amongst others, in mobility and housing. Especially car sharing services have become popular in Western Europe and North America. Beside consumer use, resource sharing is also utilized at a business or industrial level. Common applications are Groupage systems in transportation logistics , cloud computing in information processing , and R&D activities and joint product development .

3. Collaborative Manufacturing Platform

The collaborative manufacturing platform acts as a medium which connects the pillars of manufacturing. The aim is to enhance the smartness of existing models via incorporating technological enablers and integrating these models on a common platform. The model is specifically designed to cater to the needs of attaining the concept of Mass Production along with Mass Customization.

With a vision that industries will be smarter in the near future, the Collaborative Manufacturing Platform can be designed to work independently without human intervention and advantages being able to monitor, communicate events and take smart decisions briskly. The system includes the concept of Cyber-Physical systems (CPSs). However, for the proposed system to function at the foreseen level of intelligence and independence the system may take years of technological advancement and its implementation. Hence provision is made for an interface to be provided for human intervention. The interface is a web based application that can be easily implemented and assessed. More importantly, industries, as of now, can use this interface to test the project, dependencies of various factors involved in manufacturing and its impact on cost and operation. It provides and an all-in-one tool for optimisation and decision making.

The system can is intense and handles mammoth number of factors and engage into their dynamic independencies. The model can be further divided at modular levels each described as a chapter in this report along with a brief introduction to the necessary foundations mandatory for the functioning of these modules.

Breakdown of the system at modular level will yield following sections:

- Customer-Industry Interaction
- Supplier-Industry Interaction
- Interaction with Neighbouring Industry

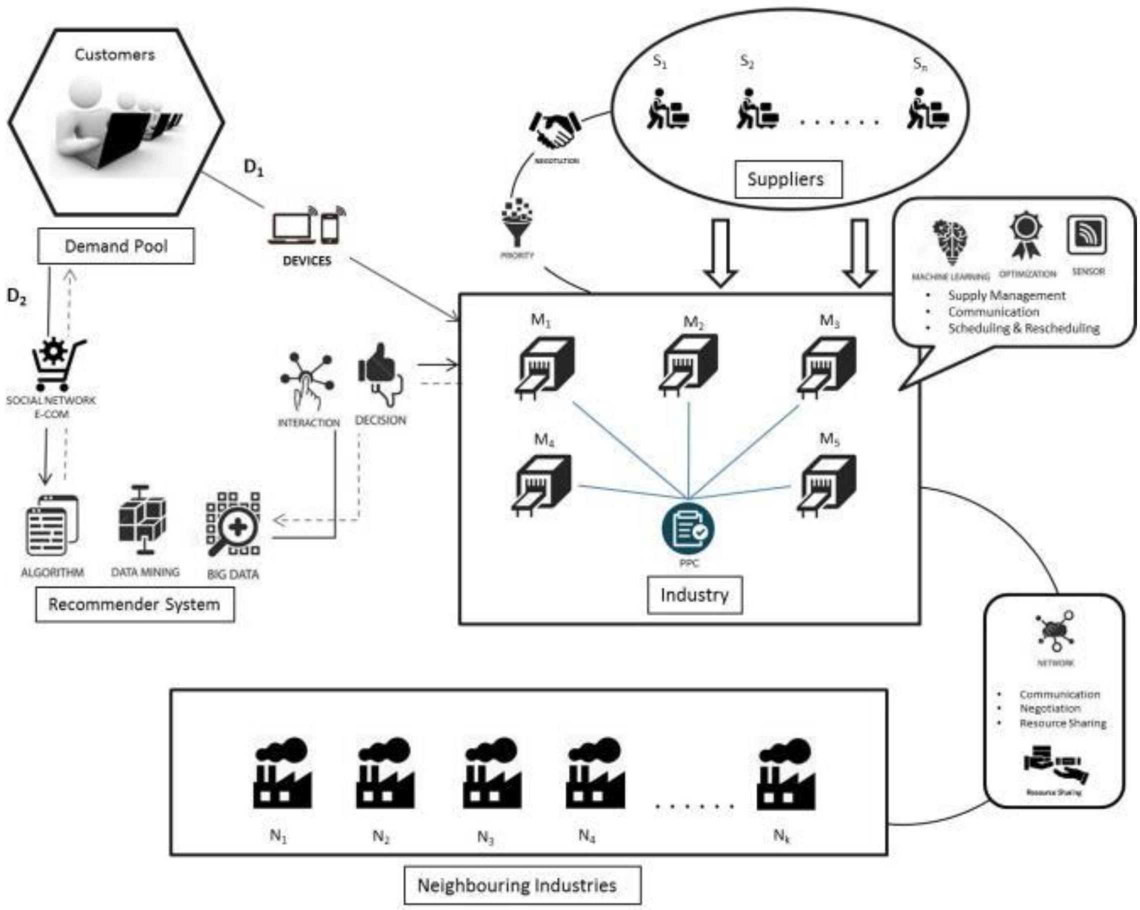


Fig. 4. Collaborative Manufacturing Platform

Model

For simulation purpose we considered a model with a pool of customers that raise the demand, a parent industry, 5 suppliers and 3 neighbouring industries all having certain characteristic specifications. Parent industry produces single type of product which is an assembly of 5 components processed on 4 different machines. These machines have specified characteristics. Suppliers have various different characteristics and rates for 3 types of raw material considered. Distance of each supplier and neighbouring industry is considered to keep the account of facility location factor. The model is flexible, perfectly suitable for study of dependencies and impact of factors in the system.

The model was considered to visualise the changes that this Collaborative Manufacturing platform will induce in manufacturing and how variable demand can be dynamically managed and cost minimised.

Working

An initial demand is generated and the parent industry checks it against the inventory department, suppliers and availability of machines. Also, time and cost of production for this particular demand is calculated. Considering failures and downtimes, maximum capacity of parent industry is calculated and this indicates the maximum number of products it can produce in a particular interval of time.

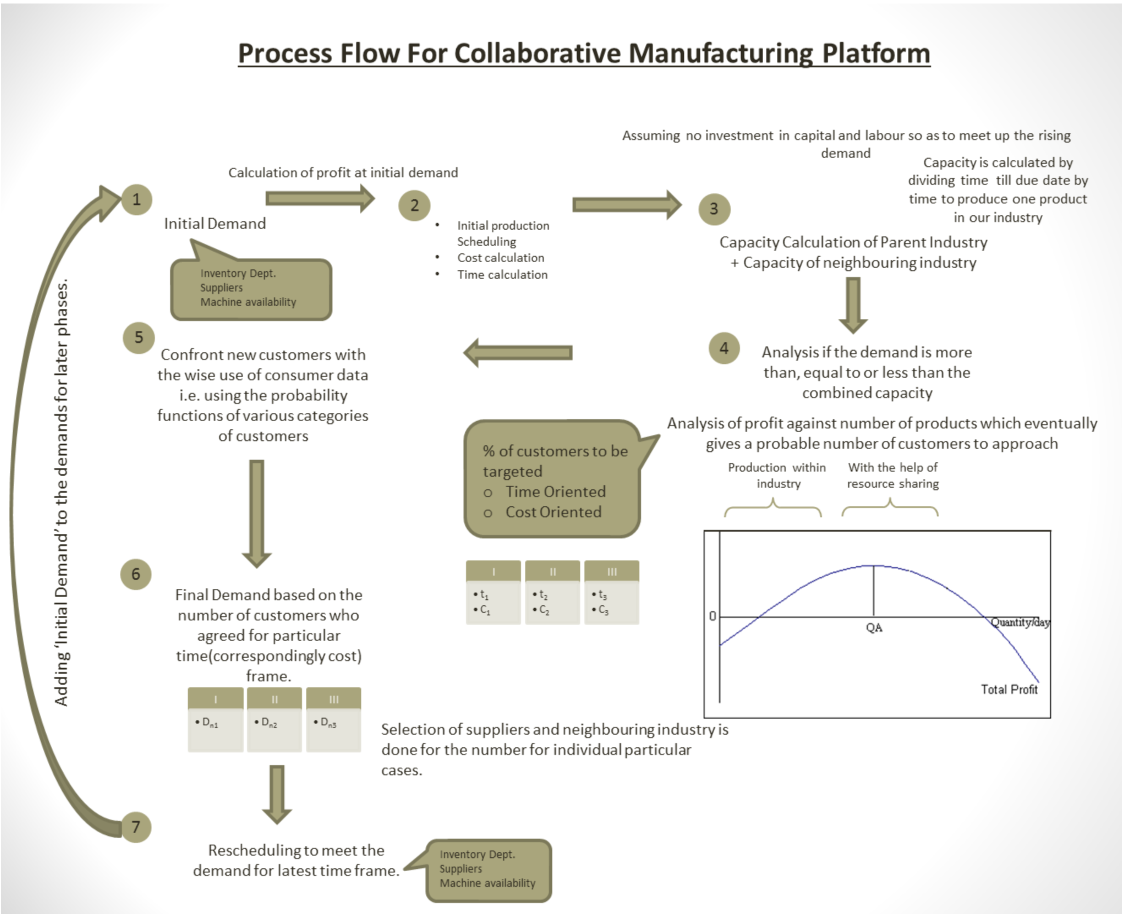


Fig. 5. Process flow diagram for Collaborative Manufacturing Platform

An analysis of profit against number of products is made which eventually gives a range of number of customers to be approached so as to increase the demand in a range where cost per piece is low. Through an efficient recommender system new customers are approached who are given an offer so as to increase the demand. This is done through big data and data mining. Simulation of this is done by creating a probability distribution model. Thereby a new demand is generated through negotiation which becomes the final demand and re-scheduling is done to meet this final demand which may involve resource sharing.

Parent Industry:

- **Capacity**:

Optimizing the schedule plan and line balancing to reach the maximum capacity. Maximum capacity within a specific time period is obtained via dividing total time by production time of one product.

- **Operation cost**:

Operation cost is a summation of preventive maintenance cost, corrective maintenance cost, cost of rejection, earliness and tardiness cost.

  - OOC = APMC + ACMC + ARC + AEC + ATC

- **Raw material Cost**:

The cost of raw materials supplied by suppliers. Prioritisation of suppliers is done on the basis of the quality of the raw material, cost of the raw material and it's availability. Quality function is a product of a weight factor and quality scale.

  - Q( ) = k x ql

Raw material cost functions are supplier specific. Suppliers are then sorted and prioritised accordingly.

- **Overhead cost**:

The indirect costs or fixed expenses of operating a business. Overhead cost for a manufacturing industry accounts for about 15% of the total cost incurred in production.

  - OC = 0.15 x TC

- **Scheduling and Re-scheduling**:

Since the demand is dynamic, there's a constant need for rescheduling.

- **Time Factor**:
    - Buffer time: The interval within which negotiation with customers, suppliers and neighboring industries is made.
    - Time to deliver: Due dates promised to customers
    - Operation time: Time taken by a particular number of products to be manufactured.

4. Customers-Industry Interaction

Customer service is the core of business and marketing. With the rise of the internet, customer service is arguably more important now than ever before. Customers write reviews of companies, interact with them on social media, and can easily shop for alternatives if their needs aren't being met. For the first time, customers are in control of the dialogue surrounding brands and companies more than the brands and companies themselves.

Globalization has increased the reach of industries and people all over the globe can be contacted and they can behave as a customer thereby increasing the demand. They are usually categorised on various basis. Going through various papers, customers in CMP are categorised as Loyal, Intermediate and Likely to reject. Each category has specific probabilities of acceptance, rejection, return and cancelation.

Other factors included in this module are Quantity based discounting (Higher the demand, higher will be the discount a firm can offer) and Time Factor (Classification of demand pool on the basis of time with respect to the urgency of requirement of product).

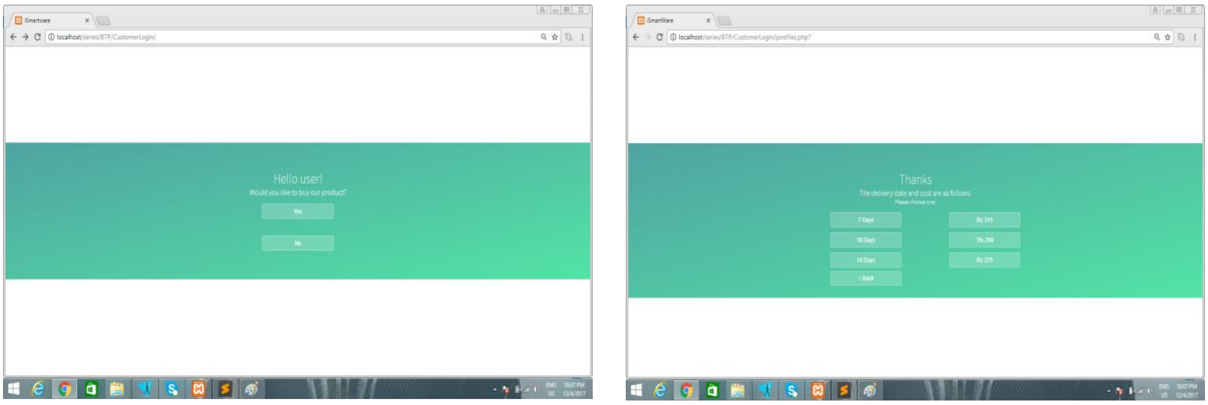


Fig. 6. Interface in CMP to interact with customer

The customer interface is interactve and is used to record responses. Customers looking for a product same as the parent industry manufacters are contacted through various means which includes the involvement of social networks and e-commerce servise providers. This is done through an effective recommender system.

4.1. Models and Algorithm

For simulation purpose, a model with probability distribution of various types of customers matching their behaviour is developed.

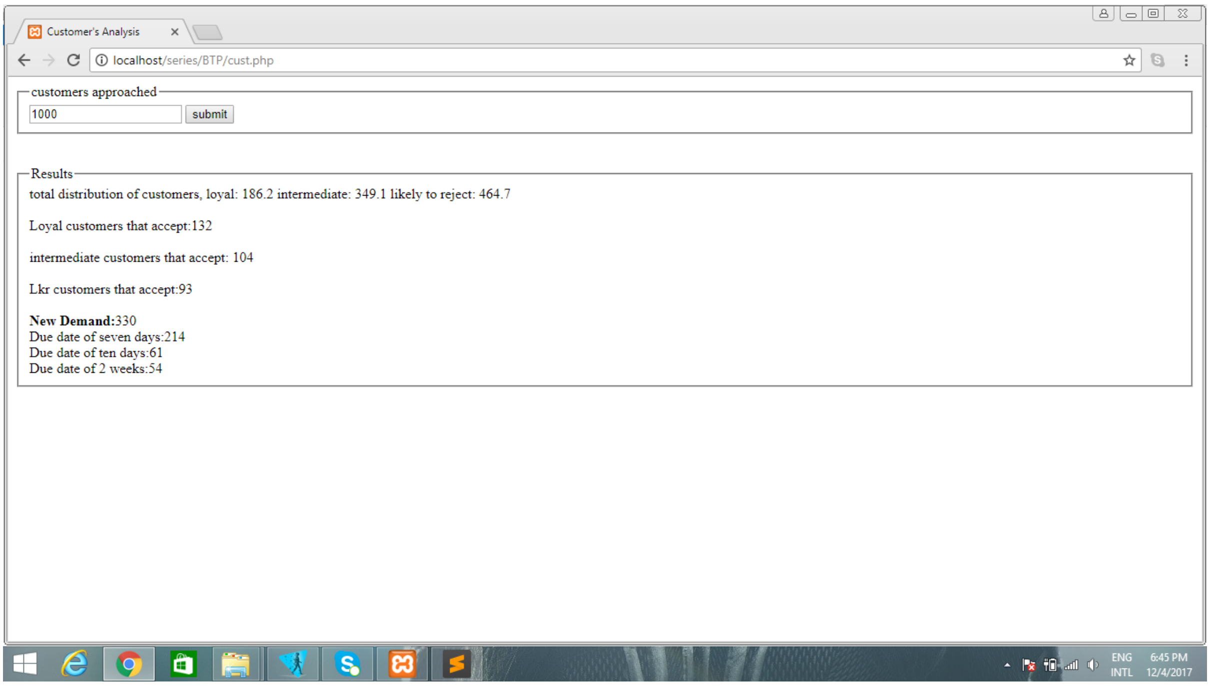


Fig. 7. Analysis of type of customers

Function to generate a random number to simulate irregularities in real market:

```
function random($p,$q){
   $r =rand($p,$q);
   $res = $r/10000;
   return $res;
}
```

To find the number of loyal customer:

```
$N=$_POST['total']; // TOTAL APPROACHED
   $loy=random(1000,3000);  // LOYAL ARE 10-30%  OF THE POOL
   $loyal=($loy*$N);
```

To find the number of loyal customer that accept:

```
$a; // Number of loyal customer
   $aLoyal;//No of loyal cust that accept
   $a=random(7000,8000);
   $aLoyal=$a*$loyal;
   echo "<br>";
   echo "Loyal customers that accept:".(int)  $aLoyal;
   echo "<br>";
```

4.2. Outcomes and Results

Number of customers to be approached with a certain (most likely) probability of acceptance is determined by iterating possibilities with probabilities and uncertainties of various types of customers.

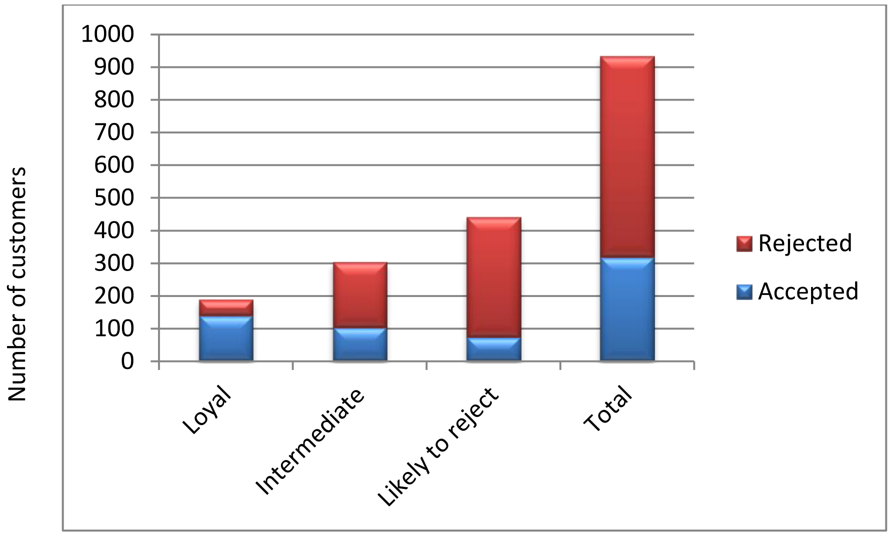


Fig. 8. Distribution of various types of customers and their quantitative analysis.

The number of customers to approach is determined by multiplying a factor with the ideal demand where the profit is maximum. Over 100 iterations, this factor was found to be 3.41.

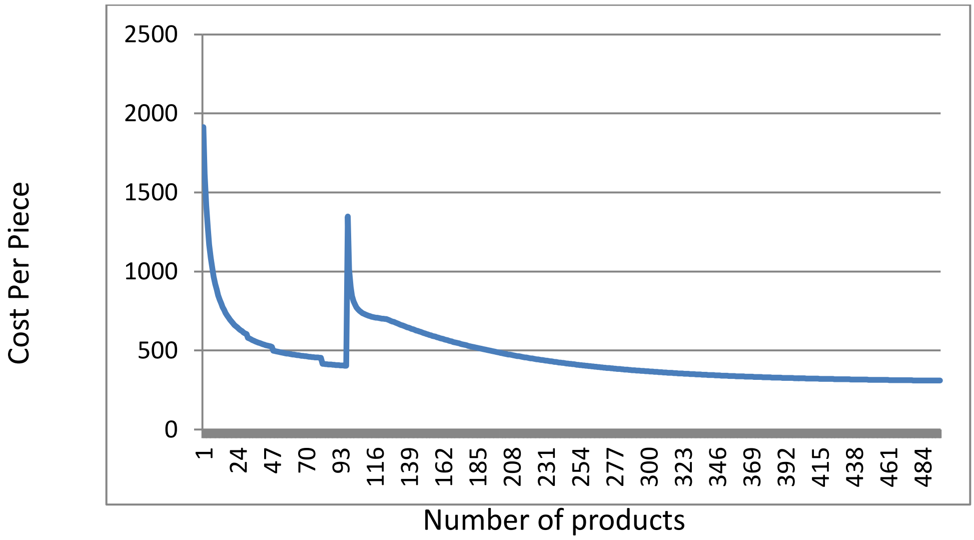


Fig. 9. CPP vs. Number of Products curve

Fig. 9. shows the trend cost per piece follows with respect to number of products. As the demand is very low (close to zero) the cost per piece is very high as the price of transportation of raw material for less number of products dominates. For such cases inventory can be used and thus that particular undesirable spike in cost per piece for less demand can be tackled. The cost per piece keeps on decreasing as the number of products produced in the parent industry itself increases till the maximum capacity is attained.

A spike in graph at observed as the number of products to be produced reaches the capacity of maximum capacity. This is due to a heavy cost of transportation and handling incurred on few products/parts that are produced and transported by neighbouring industry. An addition rental cost adds while resource sharing. When number of products made from resource sharing is significant enough such that quantity discounts overshadow the rental cost, additional benefit can be attained.

5. Supplier-Industry Interaction

A company's relationship with its suppliers has become increasingly important in the total context of the organization in the early 21st century. Companies have generally reduced the number of suppliers they buy from in order to develop long-term, mutually beneficial strategic partnerships with key suppliers. **Cost of raw material**: Each supplier would have different rates for different material. Moreover, they may supply only a specific type or raw material.

Selection of supplier is the most important step when it comes to Supplier-Industry module in CMP. The factors considered are:

- **Time factor**: This factor will consider the time in which a supplier can provide material to the industry and hence influence the 'selection of the right supplier'.

- **Quantity based pricing**: The suppliers have their own cost functions, mostly a step wise function.

  Eg(For *100<N<500, cost=50*N * 500<=N<1000, cost = 45*N) Where N is quantity of raw material ordered.

- **Quality Factor:** Each supplier have its unique quality factor which will influence the selection of the right supplier.

- **Location:** Location of suppliers will influence the transportation and handling cost. Transportation cost is a function of distance and handling cost depends upon the characteristics of the raw material and the amount supplied.

- **Brand value:** The position and status of supplier is given a weight which will influence the selection process.

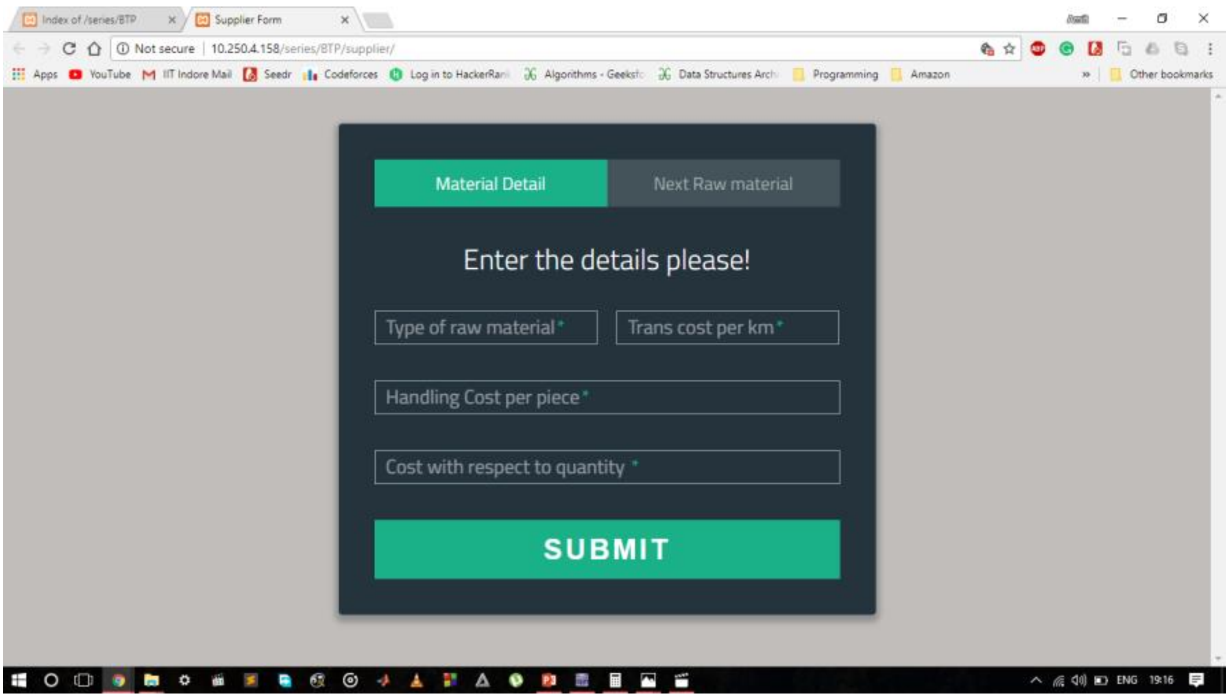
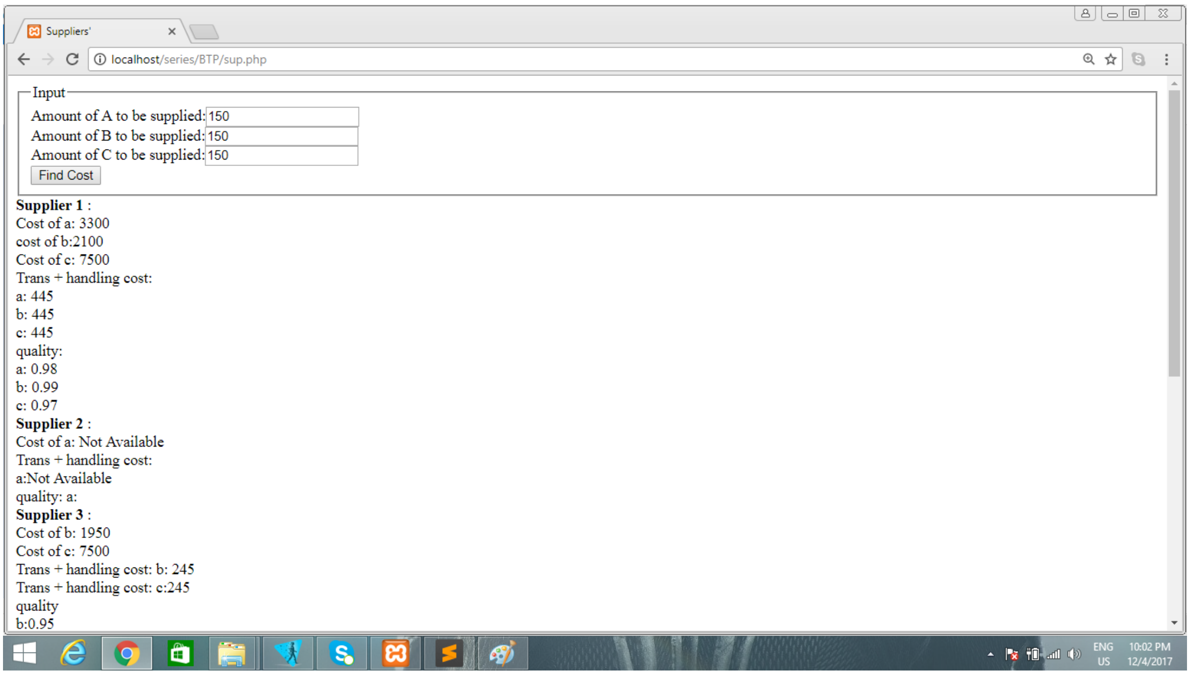


Fig. 9. Interface in CMP to interact with supplier

5.1. Models and Algorithm

Simulation of suppliers is done by assigning various characterstics to the 5 suppliers considered in our model. The price and availability of the 3 types of raw materials are different for the suppliers that are subjected to diverse distribution functions so as to simulate the real market scenario.



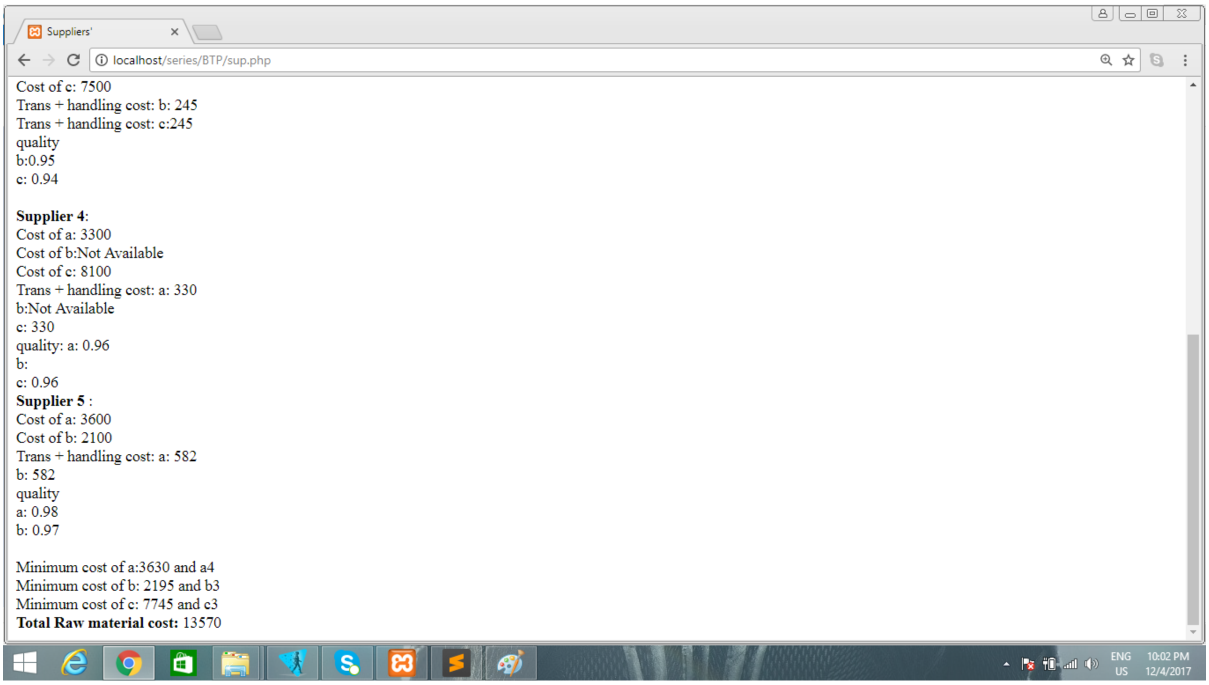


Fig. 10. Cost and availability analysis of different suppliers

Supplier function:

```
function Sup2($a, &$qa, &$qTa, &$qla) {

 $p;

 //only a- not much loss in quality as it supplies only 'a'.

 $d = 150; //distance

 // $ ql;//quality

 // $ $qa;//cost of a

 // $ $qb;//cost of b

 // $ $qc;//cost of c

 $qa = $qc = $qb = $qTa = $qTb = $qTc = 1e9;


 if (0 < $a && $a <= 100)

 {

   if(biasedRandGen(100)){

     $qa = 24 * $a;

     $qla = 0.98;

     $qTa = 4 * $d + (0.5 * $a);

   }

 }


 else if (100 < $a && $a <= 250)

 {

   if(biasedRandGen(70)){

     $qla = 0.98;

     $qa = 21 * $a;

     $qTa = 4 * $d + (0.5 * $a);

   }

 }
```

```
 else if (250 < $a && $a <= 450)
 {
   if(biasedRandGen(100)){
     $qa = 19 * $a;
     $qla = 0.98;
     $qTa = 4 * $d + (0.5 * $a);
   }
 }

 else if (450 < $a ) {
   if(biasedRandGen(70)){
     $qa = 16 * $a;
     $qla = 0.98;
     $qTa = 4 * $d + (0.5 * $a);
   }
 }
}
```

<u>Function to select the supplier in accordacne with availability and cost</u>:

```
function getCostMin($arr){
 $ret = (object) ['cost' => 1000000000, 'name' => '-1'];
            //var_dump($ret);
 for($i = 0; $i < sizeof($arr); ++$i) {
                  //var_dump($arr[$i]);
                  //var_dump($ret->cost);
  if($ret->cost > $arr[$i]->cost) {
```

```
   $ret = $arr[$i];
  }
 }
 return $ret;
 }

    $tta1=(object) ['cost' => $qa1 + $qTa1, 'name' => 'a1'];
    $tta2=(object) ['cost' => $qa2 + $qTa2, 'name' => 'a2'];
    $tta4=(object) ['cost' => $qa4 + $qTa4, 'name' => 'a4'];
    $tta5=(object) ['cost' => $qa5 + $qTa5, 'name' => 'a5'];
    $allcostA= array($tta1,$tta2,$tta4,$tta5);
  //

    $ttb1=(object) ['cost' => $qb1 + $qTb1, 'name' => 'b1'];
    $ttb3=(object) ['cost' => $qb3 + $qTb3, 'name' => 'b3'];
    $ttb4=(object) ['cost' => $qb4 + $qTb4, 'name' => 'b4'];
    $ttb5=(object) ['cost' => $qb5 + $qTb5, 'name' => 'b5'];
    $allcostB= array($ttb1,$ttb3,$ttb4,$ttb5);

    $ttc1 = (object) ['cost' => $qc1 + $qTc1, 'name' => 'c1'];

    $ttc4 = (object) ['cost' => $qc4 + $qTc4, 'name' => 'c4'];

    $ttc3 = (object) ['cost' => $qc3 + $qTc3, 'name' => 'c3'];

  /*
  $ttc1.cost=$qc1+$qTc1;
  $ttc4.cost=$qc4+$qTc4;
  $ttc3.cost=$qc3+$qTc3;
```

```
*/
$allcostC= array($ttc1,$ttc3,$ttc4);
//var_dump($allcostC);
//
$numA= getCostMin($allcostA);
$numB= getCostMin($allcostB);
$numC= getCostMin($allcostC);

return array($numA, $numB, $numC);
```

5.2. Outcomes and Results

Quantity discount plays a vital role in cost models in CPM. The cost function of raw materials supplied by suppliers is generally a stepwise, linearly decreasing or a mixed complex function. The example considered here is an example of a supplier providing raw materials with a grouped pricing. Usually a unit piece costs cheaper when the overall demand of the raw material is high.

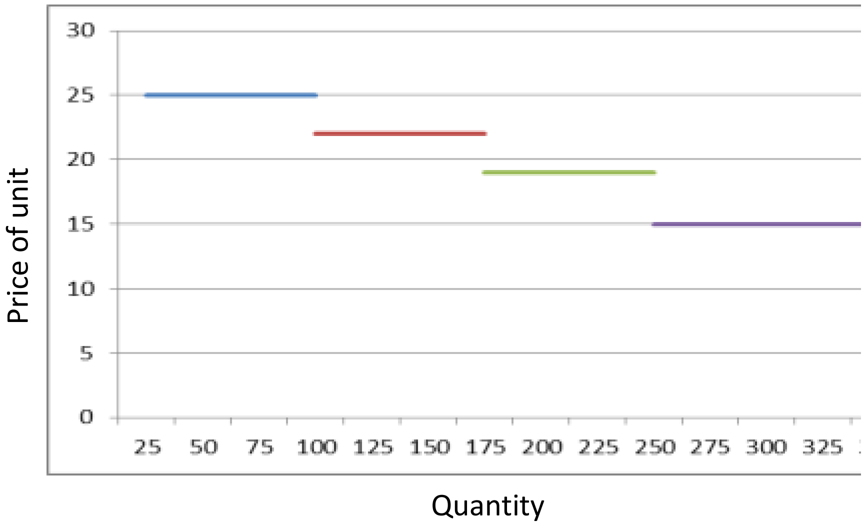


Fig. 11. Quantity based discount on price of raw material.

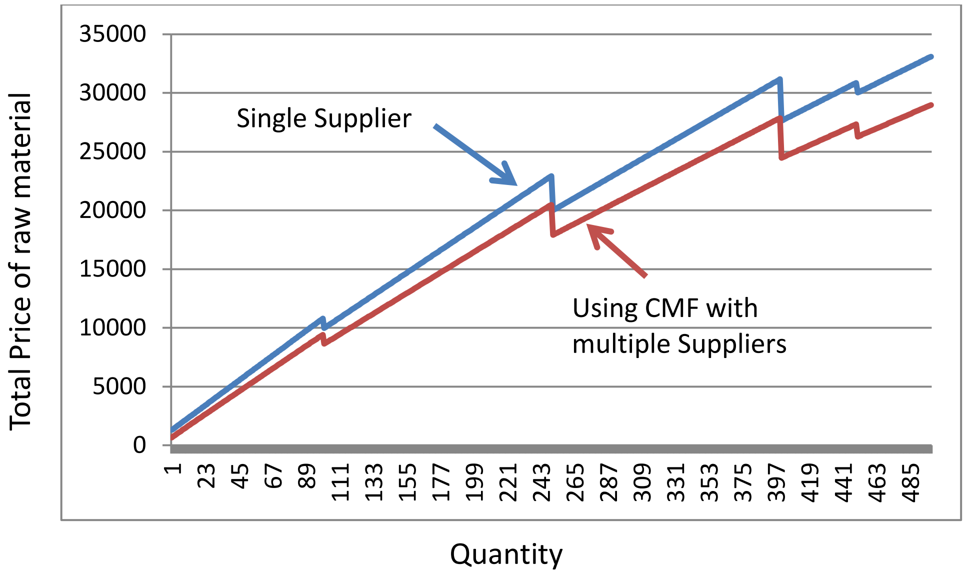


Fig. 11. Comparative result of Total raw material price w.r.t. quantity.

An effective decrease in cost was observed using the sorting and selection algorithm which considers factors like cost, location facility, availability and quality. The shift between the two curves in graph shows the difference in the total price of raw material and the profit increases with increase in quantity.

6. Interaction with Neighbouring Industry

Highly varying markets pose challenges for production and logistics companies. Above all, short product lifecycles and frequent technological changes in most industries, e.g. in consumer electronics, are drivers for fluctuations in demand. Therefore, companies have to put additional effort in keeping their production and logistics capacities in balance with these demand changes.

For collaborative manufacturing, resources from neighbouring industries can be shared to maximize profit by increasing demand. As the machines are getting smarter, their failure can be predicted or predetermined through prognostics. Hence, what neighbouring industry does is provide us an alternative workplace with its machines and infrastructure. We can direct our jobs to there for further processing in the case of machine failure or shortage. By shortage, we mean either the demand got raised more than the capacity of our workplace or the lack of spare machines in the case of machine downtime. Thus neighbouring industry plays an important role in resource sharing and can be selected among all the available industries depending on their respective cost functions.

Negotiation with neighbouring industries for resource sharing is an integral part of collaborative manufacturing platform.

- **Operation Cost**:

Operation cost is a summation of preventive maintenance cost, corrective maintenance cost, cost of rejection, earliness and tardiness cost.

OOC = APMC + ACMC + ARC + AEC + ATC

OOC = Overall operation cost

APMC = Average Preventive Maintenance Cost

ACMC = Average Corrective Maintenance Cost

ARC = Average Rejection Cost

AEC = Average Earliness Cost

ATC = Average Tardiness Cost

- **Facility Location**:

Location of neighbouring industry will influence the **transportation** and **handling cost**. Transportation cost is a function of distance and handling cost depends upon the characteristics of the product and the number of product. More valuable the product is, more is the handling cost.

$$\mathbf{T(\,) = k_1 \times d + k_2 \times N}$$

- **Additional/Rental Cost**:

Neighbouring industries usually charge an additional cost on per product basis that it produces.

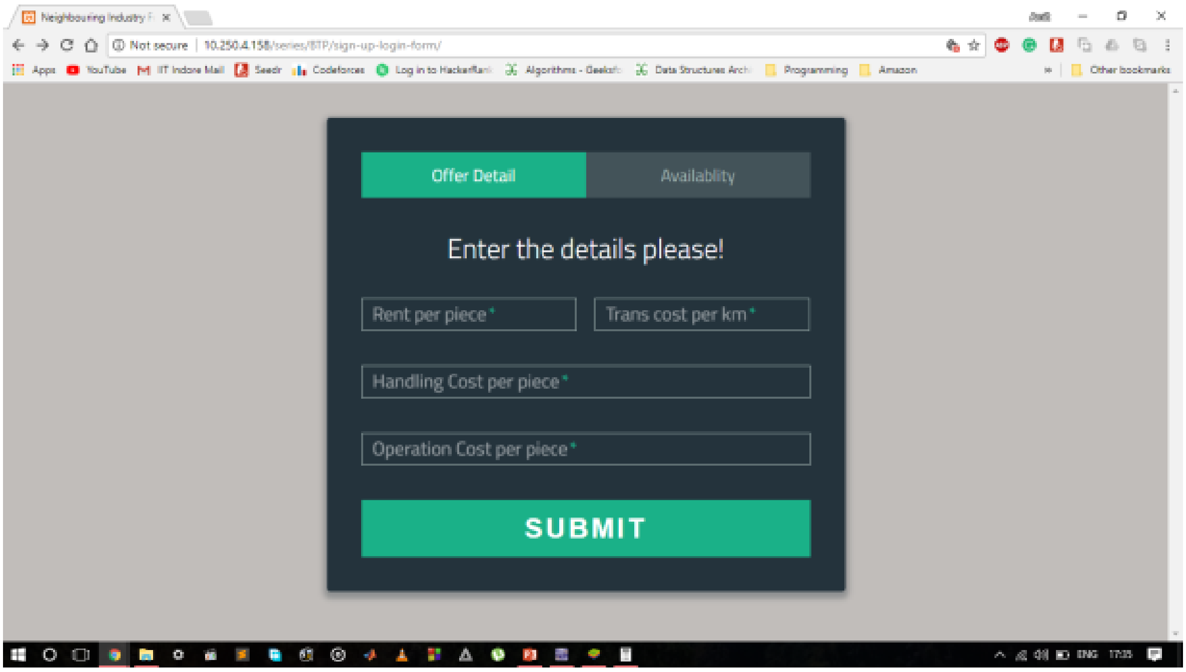
R( ) = k_3 x N

- **Raw Material Cost**:

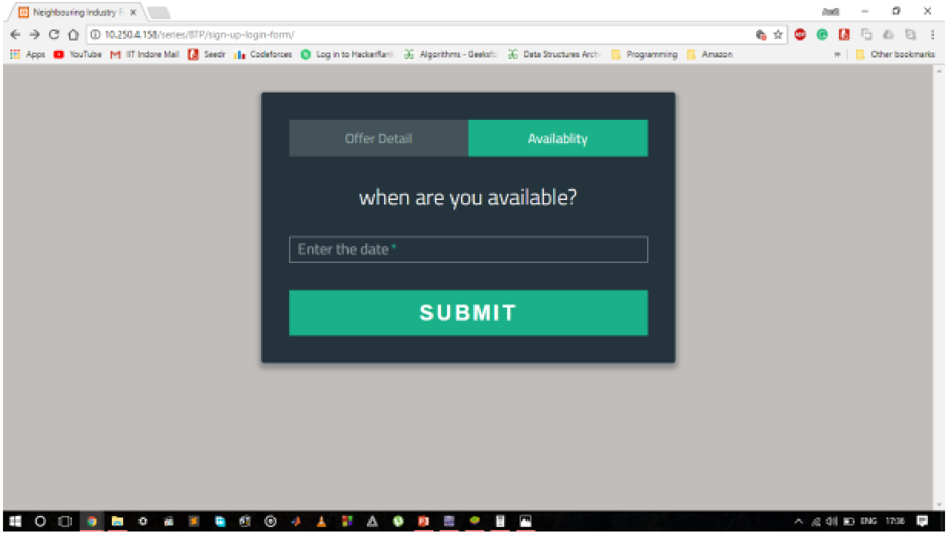
Model for raw material price for parent industry is used for neighbouring industry as well.

- **Availability**:

This factor determines if a neighbouring industry can process and fulfil the demand of parent industry or there is no idle machine available.



(a)



(b)

Fig. 12. Interface to interact with Neighbouring Industry

6.1. Models and Algorithm

<u>Calculation of cost due to neigbouring industry production</u>

```
function Ni1($N,&$costNI1,&$ren1,&$td1)

        {

        $N; // total no of products to be mfg.

                $aN1=$N;// no of raw material ‘a’ req.

                $bN1=$N;// ‘b’ req

                $cN1=$N;]// ‘c’ req

                $d1=150;//distance

                $td1=1.3*$d1 + 0.3 * $N  ;//trans + handling

                $costArray = calcCost($aN1, $bN1, $cN1,0);

                $armc1=$costArray[0]->cost + $costArray[1]->cost + $costArray[2]->cost;

//calculation of cost of raw material using supplier function

                $ren1=20.8*$N;//rent;

                $opc1=0.7*$armc1;

                $costNI1=$armc1+$ren1+$td1 + $opc1;

        }
```

Cost minimization:

```
function costMin($costNI1,$costNI2,$costNI3){



                $ttNI1=(object) ['cost' => $costNI1, 'name' => 'Ni1'];

                $ttNI2=(object) ['cost' => $costNI2, 'name' => 'Ni2'];

                $ttNI3=(object) ['cost' => $costNI3, 'name' => 'Ni3'];


                $allcostNI=array($ttNI1,$ttNI2,$ttNI3);

                $numNI=getCostMinNI($allcostNI);

                return $numNI;          # code...


        }


        function calcCostNi($n){

                $costNI1;$costNI2;$costNI3;$ren1;$ren2;$ren3;$td1;$td2;$td3;

                Ni1($n,$costNI1,$ren1,$td1);

                Ni2($n,$costNI2,$ren2,$td2);

                Ni3($n,$costNI3,$ren3,$td3);

                $totalCost=costMin($costNI1,$costNI2,$costNI3);

                return $totalCost;

}
```

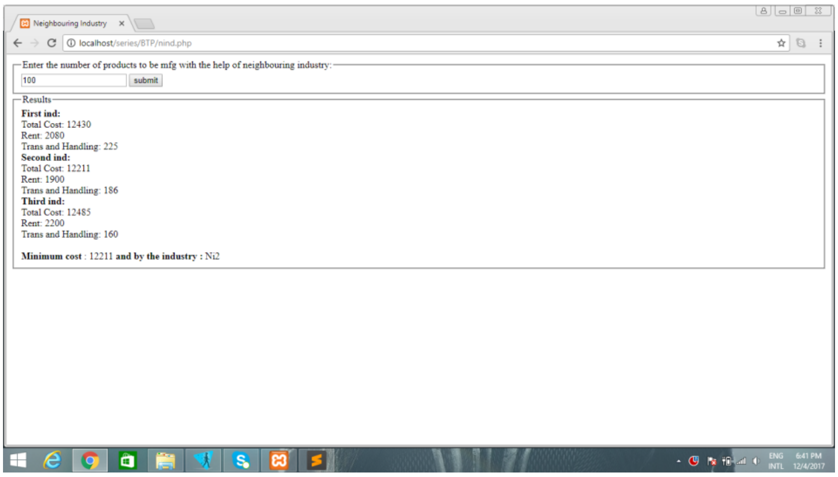


Fig. 13. Analysis of cost incurred by resource sharing through Neighbouring Industry and selection

Total cost that Neighbouring Industry charge is a summation of all costs (including addition rental cost, transportation and handling cost). Selection of neighbouring industry is done considering all the above mention factors.

6.2. Outcomes and Results

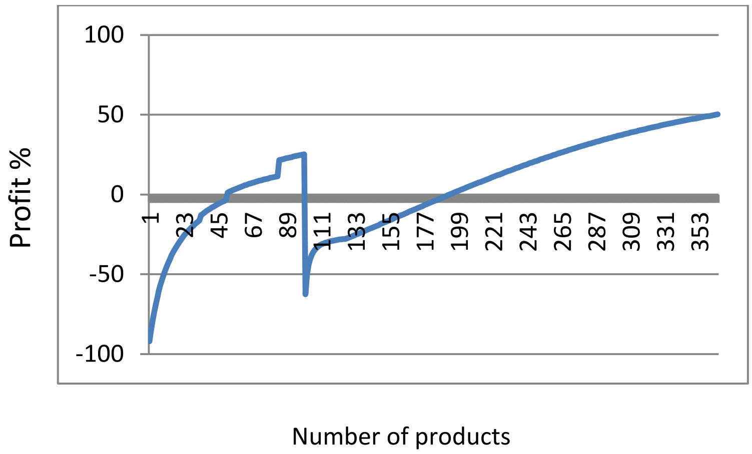


Fig. 14. Profit vs. number of products curve

- Initial Demand = 55
- Profit Margin at initial demand = 3%

Graph shows the profit over existing profit along with variation in demands.

<u>Overall Optimized cost analysis , day wise / week wise.</u>

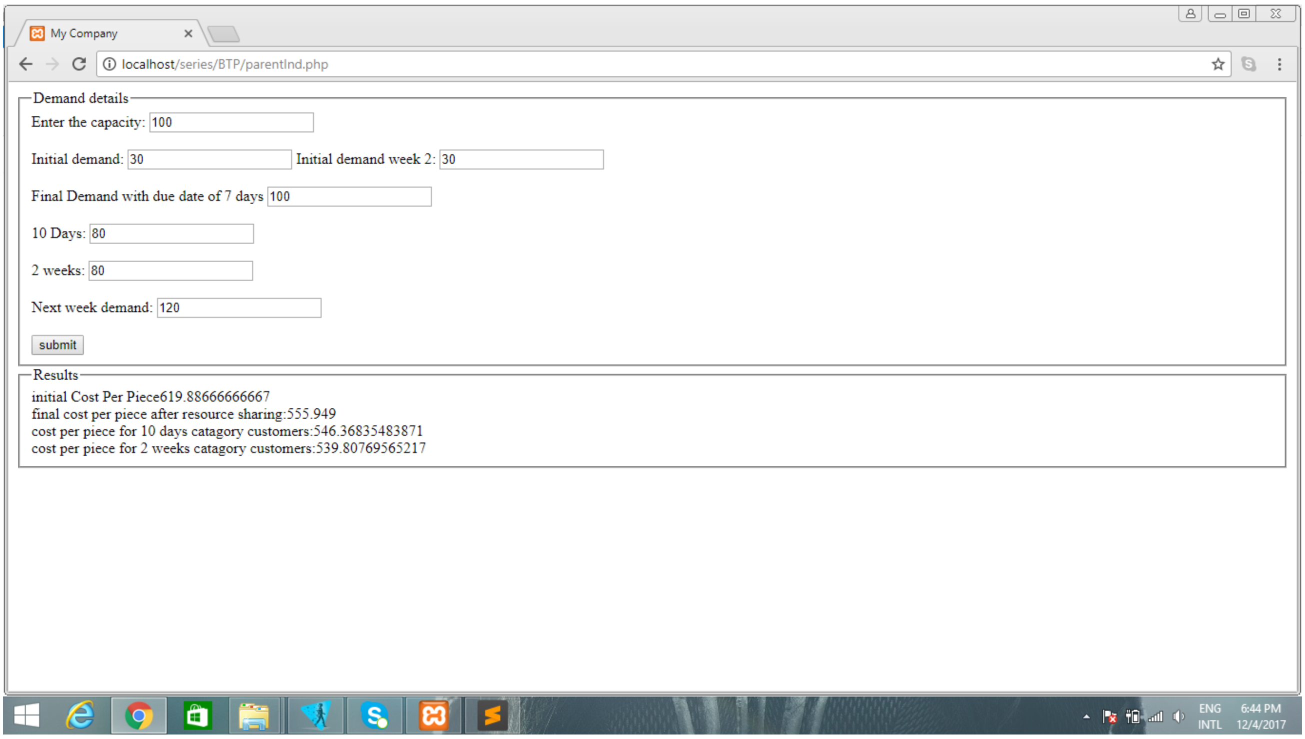


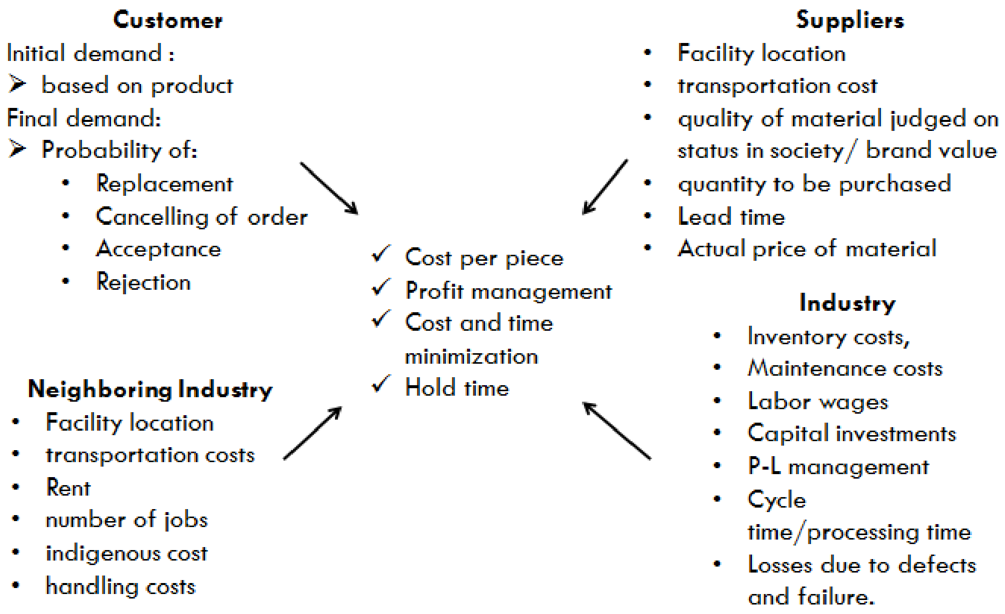
Fig. 15. Final Cost for different time frame.

```
<?php
require_once('neighUtil.php');
require_once('costUtil.php');
?>


<?php
        //initial demand:
function initialCost($initialDemand){
                $cap;//capacity
                $inDem;
                $inDem=$initialDemand;
                $costArrayI=calcCost(2*$inDem,2*$inDem,3*$inDem,0);
```

```
            $armcl=$costArrayI[0]->cost + $costArrayI[1]->cost + $costArrayI[2]->cost;// initial
raw material cost

            $opc=0.7*$armcl;

            //initial due date

            //and finally initial cost per piece


            $fCostI = ($armcl + $opc + 5000) / $inDem;

            return $fCostI;

    }


    /*Initial raw material cost array*/
```

7. Conclusion

- Proposition of the collaborative manufacturing platform which is a system that is an effort towards smart manufacturing.
- Identification of the factors influencing the production in an industry. Subsequently, categorization of these factors into the subclasses.



- *Fig. 16. Factors summarised*

- The results indicate that using Collaborative Manufacturing Platform may lead to increased profit in the existing profit.
- Overall increase in number of customer and thus increase in profit for both the customers and industry.
- Smart selection of suppliers and neighbouring industry which ensures best possible amalgamation of lowest cost, best quality and availability.
- Ideal time is significantly reduced.

On technical note, work is done to develop and implement interactive manufacturing simulation model and is expected to help in further research analysis and better decision making with increased overall profits.

There's an infinite scope of further development in this field and this concept of increasing the demand of a particular (maybe customised) product and thereby producing it on a mass scale is a totally new concept and no work has been done upon the same.

Software

The interface is developed as a webapp and is accessible to customers, suppliers and neighbouring industries for dynamic interaction and negotiation. The webapp is responsive and can be opened on any desktop or mobile browser.