Indices	
s	Raw material supplier ,raw_supplier
p	product
i	Raw material supplied ,raw_material
T	Interval time of which the raw material supplied ,time
x	Method used to refurbishment $\forall x$ refurbishment_meth
k	Method used to re design $\forall k$, redesign_method
I	value of inventory inventory
sc	Storage center storage_center
dr	Distribution center distribution_center
ds	Disassembly center disassembly center
m	Method used of manufacturing manufacture_method
o	Severity class of injury (o,…O) severity(o)

Decision variables	
S_s	Binary variable , if the raw supplier s is selected =1 , otherwise =0, $\forall s$ supplier_selected(raw_supplier)
Y_{Ts}	Binary variable, if the interval selected is a discount interval =1 , otherwise =0, $\forall T, s$ interval_selected (time, raw_supplier)
f_x	Binary variable , if the refurbishment method x is selected =1 , otherwise =0, $\forall x$ refurbishment_selected(refurbishment_meth)
G_k	Binary variable , if the redesigning method k is selected =1 , otherwise =0, $\forall k$ redesign_selected(redesign_method)
ps_s	Portion of new product of raw material supplied for each supplier $\forall s$ portion_raw(raw_supplier)
pc_x	Portion of refurbishment products of each refurbishment method $\forall x$ portion_refurb(refurbishment_meth)
Pf_k	Portion of redesigning products of each redesigning method $\forall k$ portion_redesign(redesign_method)
M_m	Binary variable , if the manufacturing method is used =1 ,otherwise =0, $\forall m$ manufacture_selected(manufacture_method)
SC_{sc}	Binary variable for storage center , if the sc is selected =1 , otherwise =0, $\forall sc$ storage_selected(storage_center)
DR_{dr}	Binary variable for Distribution center , if the dr is selected =1 , otherwise =0$\forall dr$ distribution_selected(distribution_center)
DC_{ds}	Binary variable for Disassembly center , if the dc is selected =1 , otherwise =0$\forall ds$ disassembly _selected(disassembly_center)

Parameters	
MP_p	Market price for different products made by raw materials supplied , $\forall \boldsymbol{p}$ **market_price(**product)
AC_p	Assembly cost of products $\forall p$ assembly_cost (product)

cs_p	cost of shipping the products to the storage centers. ∀ p shipping_storage_cost (product)
t^p_{sc}	Transportation cost of shipping the products to the storage centers. . ∀ p, sc transp_storage_cost (product, storage_center)
d_{sc}	Distance travelled to the storage centers, ∀ sc distance_storage(storage_center)
cd_p	cost of shipping the products to the distribution centers. ∀p shipping_distribution_cost (product)
t^p_{dr}	Transportation cost of shipping the products to the distribution centers . . ∀ p, dr transp_ distribution _cost (product, distribution_center)
d_{dr}	Distance travelled to the distribution centers , ∀ dr distance_ distribution (distribution_center)
H^p_m	# of hours needed to made products using raw materials supplied ,for ∀ p, m hours_raw(product, manufacture_method)
l	Labor cost per hour . labor_cost
cm_p	Manufacture cost of new products ∀ p manufacture_raw_cost(product)
R_s	Variable cost of products made using raw materials supplies ∀ s variable_raw_cost(raw_supplier)
Q_s	Capacity of each raw material suppliers , ∀ s raw_capacity(raw_supplier)
oc_{sT}	Manufacture cost of raw materials in different intervals , ∀ s, T manufacture_raw_cost(time, $raw\_supplier$, raw_material)
n_i^p	# of each raw material needed to make product p ∀ i, p number_raw(raw_material,product)
c_s	Ordering cost from each supplier , ∀ s order_raw_cost(raw_supplier)
MP'_p	Market price for different products made by Refurbishment , ∀ p **market_price_refurb(**product)
R_x	Variable cost of products made by Refurbishment method ∀ x variable_refurbished_cost(refurbishment_meth)
cds_p	cost of shipping the products to the disassembly centers.. ∀ p, ds shipping_ disassembly _cost (product)
t^p_{ds}	Transportation cost of shipping the products to the disassembly centers. . ∀ p, ds transp_ disassembly _cost (product, disassembly center)
D_{ds}	Distance travelled to the disassembly centers., ∀ ds distance_ disassembly(disassembly center)
df	Defective percentage of returned disassembled products . defective_percentage
h'_p	# of hours needed for Refurbished products ∀ p hours_refurbished(product)
cm'_p	Manufacture cost of Refurbished products ∀ p manufacture_refurbished_cost(product)
Q_x	Capacity of xth refurbishing methods , ∀x refurbish_method_capacity(refurbishment_meth)
c_x	Ordering Cost of refurbishment method x selected , ∀ x order_ refurbish _cost(refurbishment_meth)
MP''_p	Market price for different products made by redesigning . ∀ p **market_price_redesign (**product)
h''_p	# of hours needed for redesigning ∀ p hours_redesigned(product)
R_k	Variable cost of products made by redesigning method ∀ k variable_refurbished_cost(redesign_method)
Q_k	Capacity of kth redesigning methods , ∀k redesign_method_capacity(redesign_method)

Cf_k	Ordering Cost of redesigning method k selected , $\forall k$ order_ redesign _cost(redesign_method)
Pe	Penalty of excess production penalty_excess
I_0	Initial value of inventory initial_inventory
D	Demand demand
I_f	Final value of inventory final_inventory
invCO	Inventory cost inventory_cost
PDC_p	Pollution of shipping to the disassembly center per unit of distance $\forall \boldsymbol{p}$ **pollution_shipping_dissasembly(product)**
$Ph^p{}_m$	Pollution caused for manufacturing new products using different methods $\forall m, p$ **pollution_manufacturing (**manufacture_method**,product)**
PSC_p	Pollution of shipping to the storage center per unit of distance **pollution_shipping_storage(product)**
Ph'_p	Pollution caused for refurbished $\forall p$ pollution_refuribshed(product)
$Ph''_{p;}$	Pollution caused for redesigning products $\forall p$ **pollution_dissasembly(product)**
PDR_p	Pollution of shipping to the distribution center per unit of distance $\forall p$ **pollution_shipping_distribution(product)**
$SE^o{}_m$	Severity function for new products for different methods , $\forall m, o$ **severity_function_new(manufacture_method,severity)**
SE'_o	Severity function of refurbished methods for each severity index , $\forall o$ severity_function_refurbished (severity)
SE''_o	Severity function of redesigning methods for each severity index $\forall o$ severity_function_redesign (severity)
CSC	Capacity of storage centers . capacity_storage
CDR	Capacity of distribution center centers . capacity_distribution
CDS	Capacity of disassembly center centers . capacity_disassembly
A	Returning goal returning_goal
$\boldsymbol{b_d}$	Uncertain demand uncertain_demand
$C*_T^s$	upper bound of the discount interval T offered by supplier s , $\forall T, s$ up_bound(time, raw_supplier)
$\boldsymbol{C_s^T}$	slightly smaller than $C*_T^s$. $\forall T, s$ bound(time, raw_supplier)

Deterministic model:

$$F1 = MAX \sum_{raw\_supplier} \left(\sum_{product} \left(market\_price(product) - assembly\_cost\ (product) \right.\right.$$
$$- \sum_{storage_{center}} ((shipping\_storage\_cost\ (product) + transp\_storage\_cost\ (product, storage\_center)$$
$$* distance\_storage(storage\_center)) * \text{storage\_selected(storage\_center))}$$
$$- \sum_{\text{distribution}_{\text{center}}} ((shipping\_distribution\_cost\ (product)$$
$$+ \text{transp\_ distribution \_cost (product, distribution\_center)} * \text{distance\_distribution(distribution\_center))}$$
$$* \text{distribution\_selected(distribution\_center))}$$
$$- \sum_{\text{manufacture}_{\text{method}}} (hours\_raw(product, manufacture\_method\ ) * labor\_cost$$
$$* manufacture\_selected(manufacture\_method\ )\ ) - \text{manufacture\_raw\_cost(product)}$$
$$- \text{variable\_raw\_cost(raw\_supplier)}$$
$$- \sum_{T} \sum_{i} (manufacture\_(raw\_cost(time, raw\_supplier, raw\_material\ )))$$
$$* \text{number\_raw(raw\_material, product)} * \text{supplier\_selected(raw\_supplier)}$$
$$* \text{interval\_selected (time, raw\_supplier))}) * \text{portion\_raw(raw\_supplier)} * \text{raw\_capacity(raw\_supplier)})$$
$$- \sum_{\text{raw\_supplier}} \text{order\_raw\_cost(raw\_supplier)} * \text{supplier\_selected(raw\_supplier)}$$
$$- \sum_{\text{refurbishment\_meth}} \left(\sum_{\text{product}} (market\_(price\_refurb(product) - \text{assembly\_cost (product)}\right.$$
$$- \text{variable\_refurbished\_cost(refurbishment\_meth)} - \sum_{storage\_center} ((\ shipping\_(storage\_cost\ (product)$$
$$+ \text{transp\_storage\_cost (product, storage\_center)} * \text{distance\_storage(storage\_center))}$$
$$* \text{storage\_selected(storage\_center))} - \sum_{distribution\_center} ((shipping\_(distribution\_cost\ (product)$$
$$+ \text{transp\_ distribution \_cost (product, distribution\_center)} * \text{distance\_distribution(distribution\_center))}$$
$$* \text{distribution\_selected(distribution\_center))} - \sum_{\text{disassembly center}} ((\text{shipping\_ disassembly\_cost (product)}$$
$$+ \text{transp\_ disassembly \_cost (product, disassembly center)} * \text{distance\_ disassembly(disassembly center))}$$
$$* \text{disassembly \_selected(disassembly\_center))} + \text{defective\_percentage}/(1 - \text{defective\_percentage})$$
$$* \sum_{\text{disassembly center}} ((\text{shipping\_ disassembly\_cost (product)}$$
$$+ \text{transp\_ disassembly \_cost (product, disassembly center)} * \text{distance\_ disassembly(disassembly center))}$$
$$* \text{disassembly \_selected(disassembly\_center))} - (\text{hours\_refurbished(product)} * \text{labor\_cost})$$
$$- \text{manufacture\_refurbished\_cost(product)}) * ((1 - \text{defective\_percentage})$$
$$* portion\_refurb(refurbishment\_meth) * \text{ refurbish\_method\_capacity(refurbishment\_meth))})$$
$$- \sum_{\text{refurbishment\_meth}} (\text{order\_ refurbish \_cost(refurbishment\_meth)}$$
$$* \text{refurbishment\_selected(refurbishment\_meth))}$$
$$+ \sum_{\text{redesign\_method}} \left(\sum_{\text{product}} (\textbf{market\_(price\_redesign (product)}\right.$$
$$- \sum_{distribution\_center} ((shipping\_(distribution\_cost\ (product)$$
$$+ transp\_distribution\_cost\ (product, distribution\_center\ ) * 2 * \text{distance\_travelled(distribution\_center))}$$
$$* \text{distribution\_selected(distribution\_center))} - (\text{hours\_redesigned(product)} * labor\_cost))\right)$$
$$- \text{variable\_refurbished\_cost(redesign\_method)} * (\text{portion\_redesign(redesign\_method)}$$
$$* \text{redesign\_method\_capacity(redesign\_method))})$$
$$- \sum_{\text{redesign\_method}} (\text{order\_ redesign \_cost(redesign\_method)} * redesign\_selected(redesign\_method))$$
$$- \text{penalty\_excess} * (\ \ \text{initial\_inventory}$$

$$+\sum_{\text{raw\_supplier}}(\text{portion\_raw(raw\_supplier)} * \text{raw\_capacity}(raw\_supplier)) + ((1 - defective\_percentage\ )$$
$$* \sum_{\text{refurbishment\_meth}} (portion\_refurb(refurbishment\_meth\ )$$
$$* \text{refurbish\_method\_capacity(refurbishment\_meth))}$$
$$+\sum_{\text{redesign\_method}} (\text{portion\_redesign(redesign\_method)} * \text{redesign\_method\_capacity(redesign\_method))}$$
$$- demand - \text{final\_inventory}) - \text{inventory\_cost} * \text{final\_inventory}$$

$$F2 = MIN\Bigg(\sum_{sraw\_supplier}\Big(\sum_{\text{product}}\Big(\sum_{\text{storage}_{\text{center}}}(pollution\_(shipping\_storage(product)\ * \text{storage\_selected(storage\_center)}$$
$$* distance\_storage(storage\_center)) + \sum_{distribution_{center}} (pollution_{shipping_{distribution(product)}})$$
$$* distance\_travelled(distribution\_center) * distribution\_selected(distribution\_center)))$$
$$* \text{portion\_raw(raw\_supplier)} * \text{raw\_capacity(raw\_supplier))}$$
$$+\sum_{\text{refurbishment\_meth}}\Big(\sum_{\text{product}}\Big(\sum_{\text{storage\_center}}(\text{pollution\_shipping\_storage(product)}$$
$$* distance\_storage(storage\_center) * \text{storage\_selected(storage\_center))}$$
$$+\sum_{\text{distribution\_center}}(pollution\_shipping\_distribution(product)$$
$$* distance\_distribution(distribution\_center) * distribution\_selected(distribution\_center))$$
$$+\sum_{\text{disassembly center}}(pollution\_shipping\_dissasembly(product)$$
$$* distance\_\ disassembly(disassembly\ center) * disassembly\ \_selected(disassembly\_center))$$
$$- defective\_percentage/(1 - defective\_percentage)$$
$$*\sum_{\text{disassembly center}}(pollution\_shipping\_dissasembly(product)$$
$$* distance\_\ disassembly(disassembly\ center) * disassembly\ \_selected(disassembly\_center))) * ((1$$
$$- defective\_percentage\ ) * portion\_refurb(refurbishment\_meth\ )$$
$$* refurbish\_method\_capacity(refurbishment\_meth)\ ))$$
$$+\sum_{\text{redesign\_method}}\Bigg(\sum_{\text{product}}\Big(\sum_{distribution\_center}(pollution\_shipping\_distribution(product) * 2$$
$$* distance\_travelled(distribution\_center) * distribution\_selected(distribution\_center)))$$
$$* (\text{portion\_redesign(redesign\_method)} * \text{redesign\_method\_capacity(redesign\_method))}\Bigg)$$
$$+\sum_{\text{raw\_supplier}}\Big(\sum_{\text{product}}\Big(\sum_{manufacture_{method}}(\text{pollution\_manufacturing (manufacture\_method, product)}$$
$$* portion\_raw(raw\_supplier\ )\ * \text{raw\_capacity(raw\_supplier)}$$
$$* manufacture\_selected(manufacture\_method\ )))\ )$$
$$+\sum_{\text{refurbishment\_meth}}\Big(\sum_{\text{product}} pollution\_refuribshed(product)\ * portion\_refurb(refurbishment\_meth\ )$$
$$*\ refurbish\_(method\_capacity(refurbishment))\ )$$
$$+\sum_{\text{redesign\_method}}\Big(\sum_{\text{product}} pollution\_dissasembly(product)\ * portion\_redesign\ (redesign\_method\ )$$
$$* redesign\_method\_capacity(redesign\_method)\Bigg)\Bigg)$$

$$f3 = \sum_{o=1}^{O} \sum_{manufacture\_method} (manufacture\_selected(manufacture\_method) * e^{o-\Sigma\frac{o}{O}} * Severity\_function\_new(manufacture\_method, severity) * \sum_{raw\_supplier} \sum_{\text{product}} \frac{20000}{\mathbf{hours\_raw(product, manufacture\_method)} * \mathbf{portion\_raw(raw\_supplier)} * \mathbf{raw\_capacity(raw\_supplier)}}) + \sum_{o=1}^{O} e^{o-\Sigma\frac{o}{O}} * severity\_(function\_refurbished\ (severity)) * \sum_{refurbishment\_meth} \sum_{\text{product}} \frac{20000}{hours\_refurbished(product) * (1-df) * portion\_refurb(refurbishment\_meth) * refurbish\_method\_capacity(refurbishmen\_meth} + \sum_{o=1}^{O} e^{o-\Sigma\frac{o}{O}}\ severity\_(function\_redesign\ (severity)) * \sum_{redesign\_method} \sum_{\text{product}} \frac{20000}{hours\_redesigned(product) * portion\_redesign(redesign\_method) * redesign\_method\_capacity\ (redesign\_method)}$$

S.T

$$portion\_raw(raw\_supplier) * \text{raw\_capacity(raw\_supplier)} \leq \text{up\_bound(time, raw\_supplier)} * \text{interval\_selected (time, raw\_supplier)} \quad \forall \text{raw\_supplier}, time$$

$$\text{portion\_raw(raw\_supplier)raw\_capacity(raw\_supplier)} \geq \text{bound(time} - 1, \text{raw\_supplier)} * \text{interval\_selected (time, raw\_supplier)}\ \forall \text{raw\_supplier}, time$$

$$\text{interval\_selected (time, raw\_supplier)} = 1\ if\ selected\ , otherwise = 0$$

$$\sum_{raw\_supplier} \sum_{\text{timel}} \text{interval\_selected (time, raw\_supplier)} \leq 1\ \forall \text{raw\_supplier}, time$$

$$\text{capacity\_storage} \geq \sum_{\text{raw\_supplier}} portion\_raw(raw\_supplier) * \text{raw\_capacity(raw\_supplier)} + (1 - \text{defective\_percentage}) \sum_{\text{refurbishment\_meth}} portion\_refurb(refurbishment\_meth) * \text{refurbish\_method\_capacity(refurbishment}$$

$$\text{capacity\_distribution} \geq \sum_{\text{raw\_supplier}} portion\_raw(raw\_supplier) * raw\_capacity(raw\_supplier) + (1 - \text{defective\_percentage}) * \sum_{\text{refurbishment\_meth}} portion\_refurb(refurbishment\_meth) * \text{refurbish\_method\_capacity(refurbishment} + \sum_{redesign\_method} \text{portion\_redesign(redesign\_method)} * \text{redesign\_method\_capacity(redesign\_method)}$$

$$\text{capacity\_disassembly} \geq \sum_{\text{refurbishment\_meth}} portion\_refurb(refurbishment\_meth) * refurbish\_method\_capacity(refurbishment$$

$$\text{portion\_raw(raw\_supplier)} \leq \text{supplier\_selected(raw\_supplier)}\ ,\forall\ \text{raw\_supplier}$$

$$portion\_refurb(refurbishment\_meth) \leq refurbishment\_selected(refurbishment\_meth)\ ,\forall\ \text{refurbishment\_meth}$$

$$\text{portion\_redesign(redesign\_method)} \leq \text{redesign\_selected(redesign\_method)}$$

$$\forall\ \text{redesign\_method}$$

$$\text{initial\_inventory} + \sum_{\text{raw\_supplier}} portion\_raw(raw\_supplier) * \text{raw\_capacity(raw\_supplier)} + (1 - \text{defective\_percentage}) * \sum_{\text{refurbishment\_meth}} portion\_refurb(refurbishment\_meth) * \text{refurbish\_method\_capacity(refurbishment} + \sum_{\text{redesign\_method}} \text{portion\_redesign(redesign\_method)} * \text{redesign\_method\_capacity(redesign\_method)} - \text{final\_inventory} \geq demand$$

$$(1 - \text{defective\_percentage}) * \sum_{\text{refurbishment\_meth}} \text{portion\_refurb(refurbishment\_meth) refurbish\_method\_capacity(refurbishment} + \sum_{\text{redesign\_method}} \text{portion\_redesign(redesign\_method)} * \text{redesign\_method\_capacity(redesign\_method)} \geq \text{returning\_goal} * demand$$

$$\text{defective\_percentage} \leq 1$$

$$\text{portion\_raw(raw\_supplier), portion\_refurb(refurbishment\_meth), portion\_redesign(redesign\_method)} \geq 0\ ,\forall \text{raw\_supplier, refurbishment\_meth, redesign\_method}$$

$$\text{supplier\_selected(raw\_supplier), refurbishment\_selected(refurbishment\_meth) ,redesign\_selected(redesign\_method)}$$

$$, \text{manufacture\_selected}(manufacture\_method), \in \{0,1)$$

Multiple objectives will be solved by the **weighted sum model**

$$\max w_1\theta_1F_1 - w_2\theta_2F_2 - w_3\theta_3F_3$$

$$w_i \geq 0\ ,\forall i$$

$$\sum_{0}^{i=3} w_i = 1$$