ANALYSIS OF THE RECYCLING-ORIENTED MANUFACTURING SYSTEMS IN CONSIDERATION OF ENERGY CONSUMPTION AND COST IN MANUFACTURING PROCESS

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Abstract:
Green and clean environments are watchwords in the current society. Government supported activities are directed towards making the surroundings cleaner and greener. Many manufacturers are of course tackling the problems positively by themselves. However, there are many contraries to each other in procedures. In this paper, a model of recycling-oriented manufacturing systems is proposed, which is for "synthetic evaluation", and the flow of material, energy, money, and information are discussed. The optimization of the model is discussed with the flows.

Keywords: *recycling-oriented manufacturing systems, mass production, mass consumption, mass disposal, material flow, energy flow, money flow, information flow*

1. Introduction

Soon after the industrial revolution, the productivity of manufacturers has been improving tremendously for more than two hundred years. As a result of this activity, mass production, mass consumption, and mass disposal have taken a firm hold on our life, and people are well off in material terms today. However, the mass production, mass consumption, and mass disposal are causing environmental problems at the present day. Many kinds of recourses have been depleted, and the reckless deforestation is destroying ecological systems. The increase of CO_2 produced by energy consumption is promoting global warming. There are many serious problems caused due to mass production, mass consumption and mass disposal[1],[2],[3].

If the mass production stops, these environmental problems can be controlled. On the other hand, the scale of the mass production and mass consumption influences the world economic condition. If we give up the mass production and mass consumption for the environment, the money flow has to decrease rapidly, and the world economy collapses. Therefore it is important to find a way in which the environmental condition and the economic condition both are comparative[4],[5]. The authors believe that one of the ways is " Recycle Oriented Manufacturing Systems". In this paper, a model of recycle oriented manufacturing system that can cope with the environment problems and the economical problem is proposed.

2. The mass production, mass consumption, and mass disposal systems

Fig. 1 shows the material flow in the mass production, mass consumption, and mass disposal systems. In these systems, raw material is gathering from the natural world, and material, parts and end products are produced in turn. The products are consumed and disposed of to the natural world.

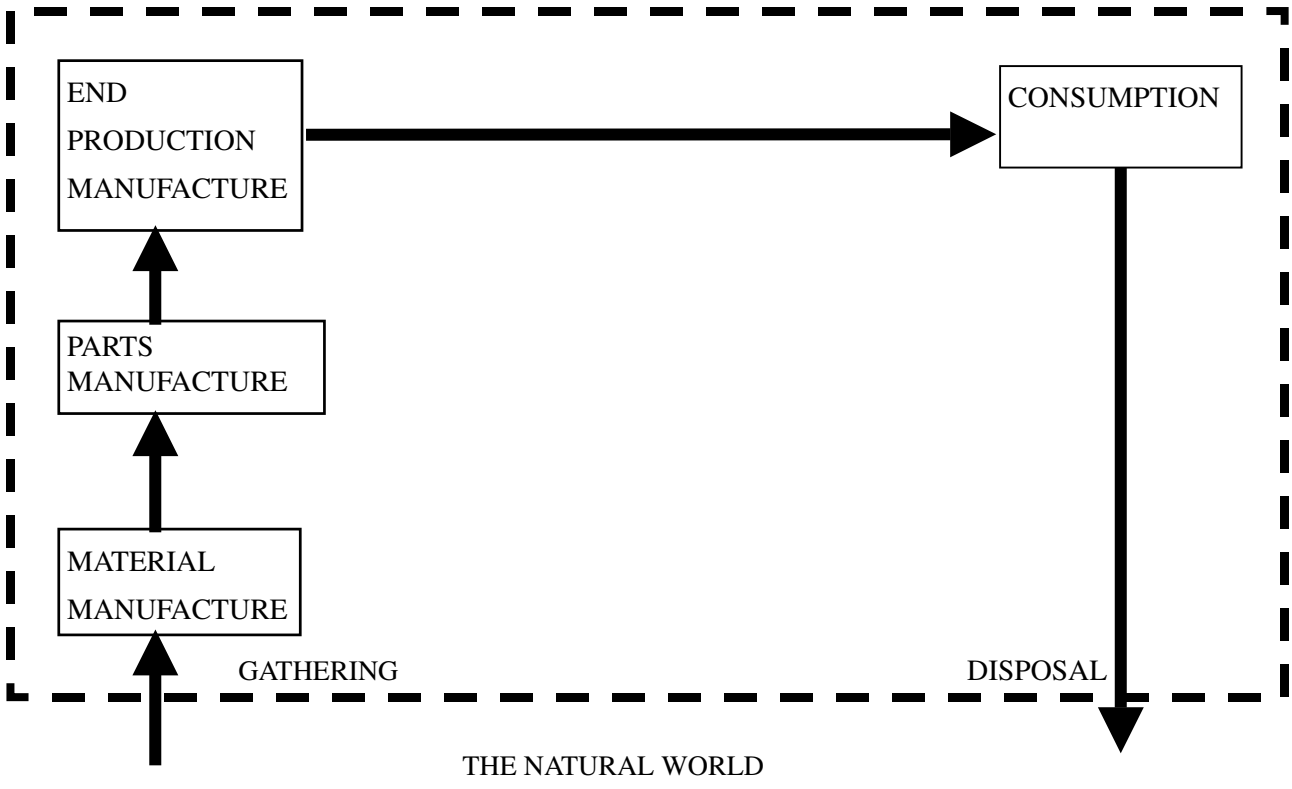

Figure 1. The material flow in mass production, mass consumption, and mass disposal.

The material flow, energy flow, information flow, and money flow in the mass production, mass consumption, and mass disposal systems are given in Fig. 2. Energy is consumed by all manufactures, consumers and during the transport. In the money flow, material manufacturers get

prices for material from parts manufacturers, and the parts manufacturers sell their parts to the end products manufacturers. Consumers buy the end products, and after their use the end products are disposed at governmental expense. The author would like to say if money flows well, material can flow in exchange for money, the rule should be kept in recycle-oriented manufacturing systems. It means even if money does not flow, material cannot flow smoothly.

The information flow is very similar to money flow because the information is transmitted from a person who needs something to a person who can supply something for the user. Along the information flow, a material is carried from the supplier to the user, and money is paid from the user to the supplier. That is why information flow is similar to money flow. As shown in Fig.2 there are two different flows between information flow and money flow: 1) government pays costs to junk dealer and 2) material manufacturers get information from the natural world.

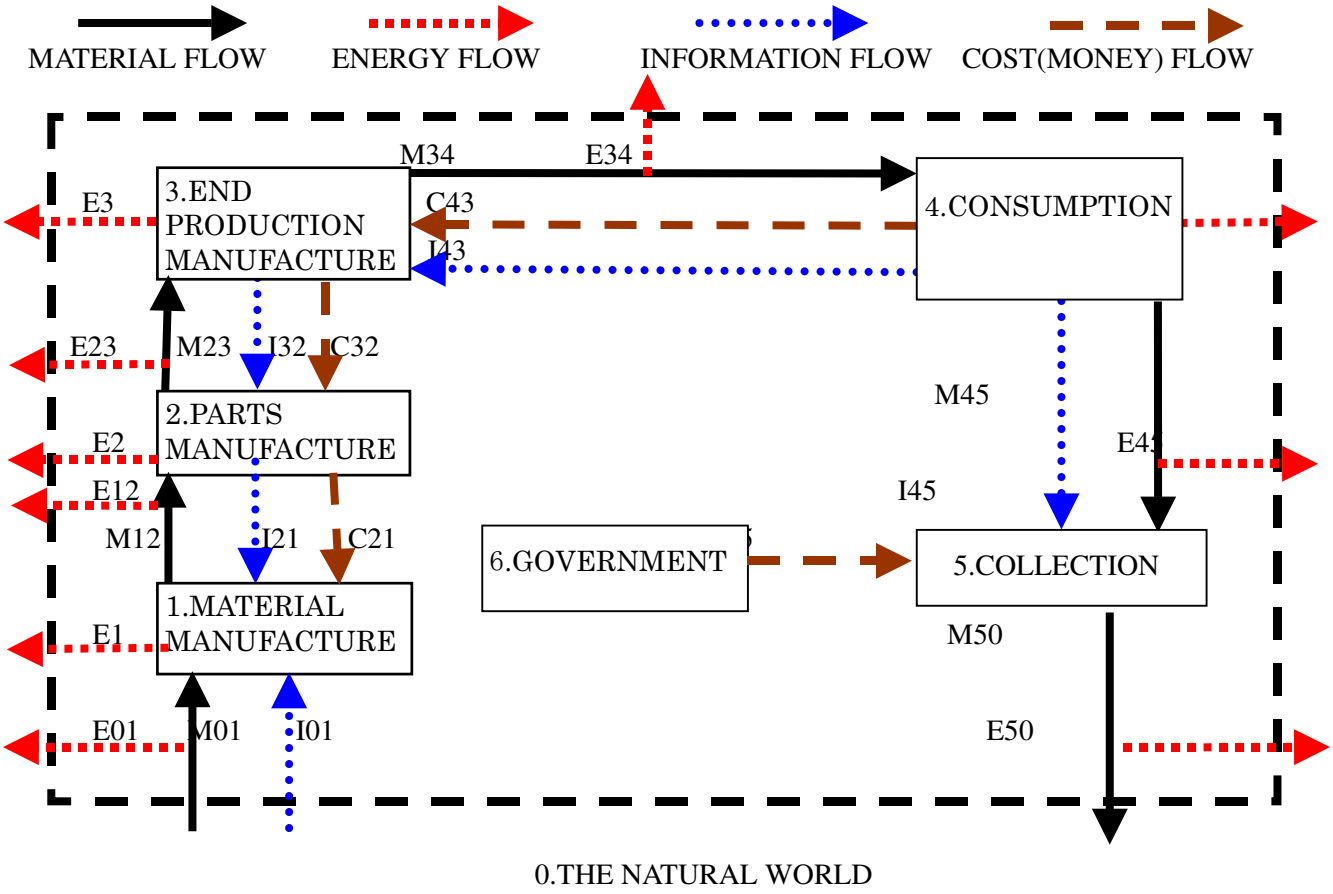

Figure 2. The flow of material, energy, information and money in mass production, mass consumption, and mass disposal

3. The material flow of recycling-oriented manufacturing systems

In the recycle-oriented manufacturing systems, used products are collected from consumers and dismantled or segregated. After the process, parts that can be used as new parts by repairing are carried to manufacturers for reclamation of the parts. Then, these parts are used by the end products manufacturers. Parts that cannot be used for new parts as such are reclaimed to material. The materials are used at parts manufacturers. This recycling ration on mineral resources is of course, a better option to save material and the environment. Because, there are limits on all mineral resources. Regarding biological resources (forest, food, etc) the regenerative power should be the limit. If all products are taken in the recycling material flow, the recycle ratio can achieve one hundred percent. Fig.3 gives this flow.

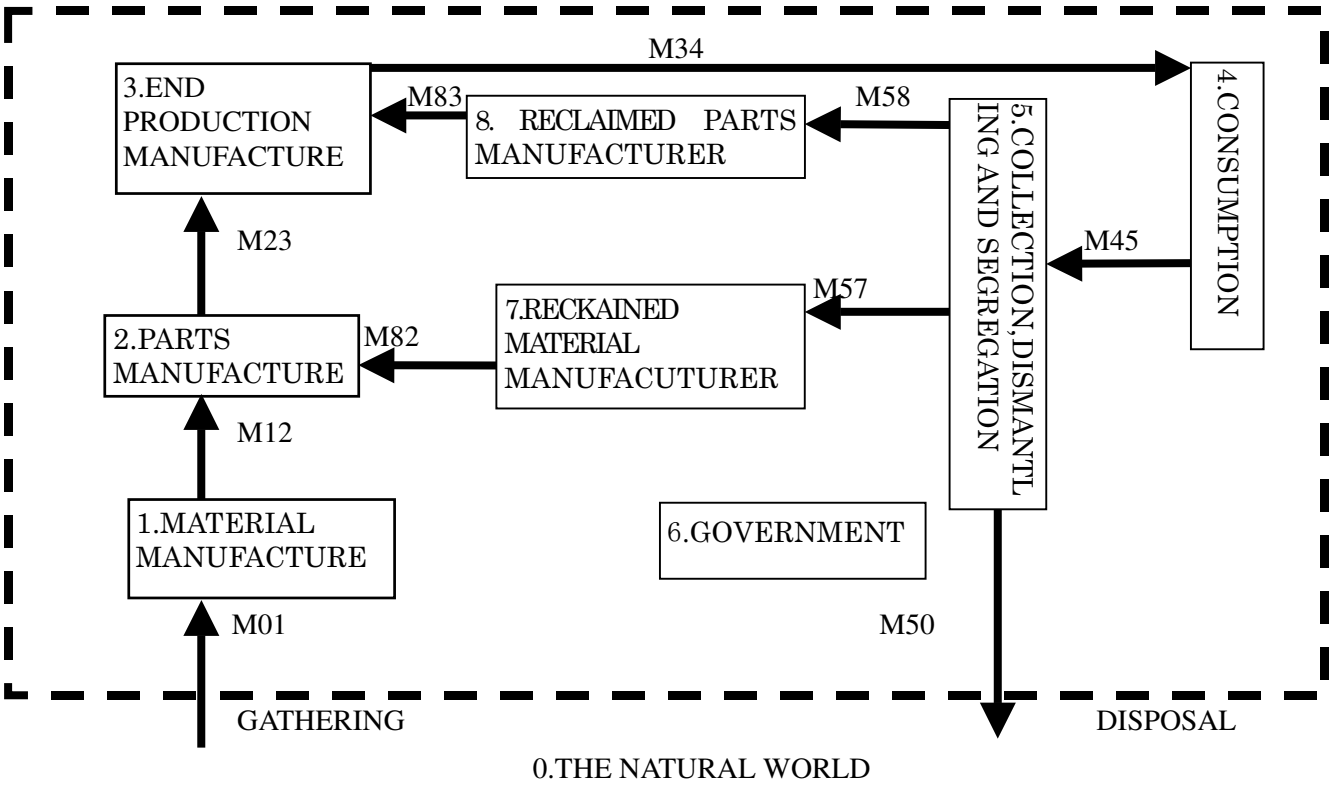

Figure 3 The material flow of recycling-oriented manufacturing systems

4. The energy flow of recycling-oriented manufacturing systems

Fig.4 shows the energy flow of recycling-oriented manufacturing systems. Energy is consumed by all manufactures, consumers, and during the transports as mass production, mass consumption, and mass disposal.

The most important issue is how much energy the manufacturing systems can use. If earth is a closed system, entropy must increase by energy consumption, but entropy is given off to outer space as low temperature radiation. Therefore how much entropy earth can give off becomes a key point for the issue. The power of low temperature radiation is dependent on the circulation of the atmosphere and water of the earth, and the condition of circulation of air and water of the earth is influenced by ecological circulation. It means how to change ecological circulation for increasing circulation of air and water of the earth is important for the energy consumption of the recycling-oriented manufacturing systems, but this problem is not discussed here. Just the authors would like to say that there is a limit on the energy flow in the recycle-oriented manufacturing systems.

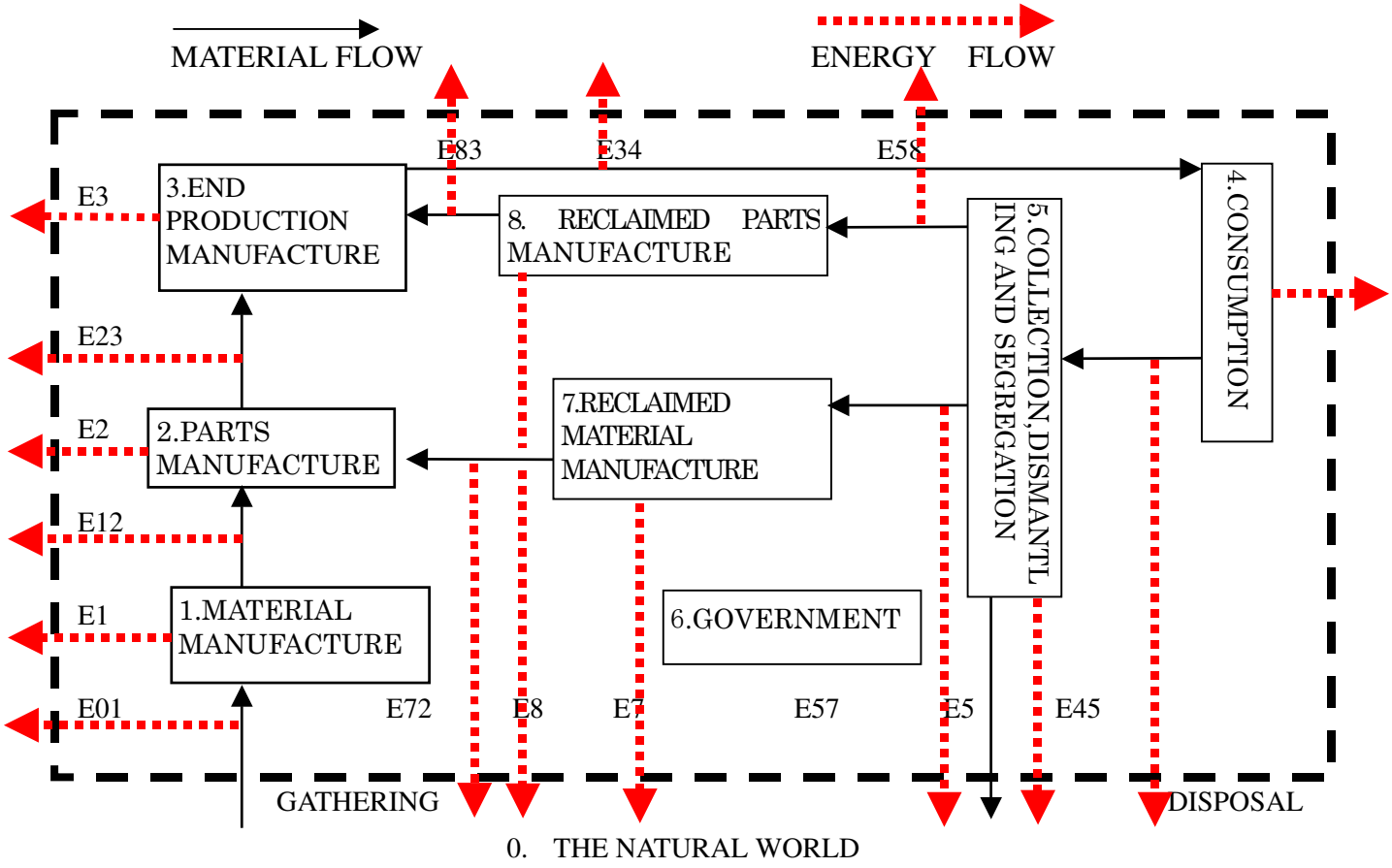

Figure 4. The flow of energy and material in recycling-oriented manufacturing systems

5. The money flow of recycling-oriented manufacturing systems

The authors believe if money can flow from one person to the other, material flows smoothly in the reverse direction of the money flow. To realize the recycling-oriented manufacturing systems, material must flow cyclically and when there is a piling point in the flow, money should be moved to a suitable place to make a smooth flow. As shown in Fig. 5, the authors believe that government should loan/invest money to small parts manufacturers and end products manufacturers, and the amount of the investing money have to be proportion to the amount of reclaimed material and reclaimed parts. By this way, end products manufacturers can buy reclaimed parts, if the total cost of reclaimed parts is not higher than the virgin parts, and parts manufacturers are also buy reclaimed materials, if the total cost of reclaimed materials is cheaper than the total cost of virgin materials. If reclaimed manufacturers can sell their parts to small parts manufacturers and end products manufacturers, they may intend to buy segregated material and parts from the industry that collects used products and the industry will also try to get used productios from consumers. By these activities, materials can flow cyclically.

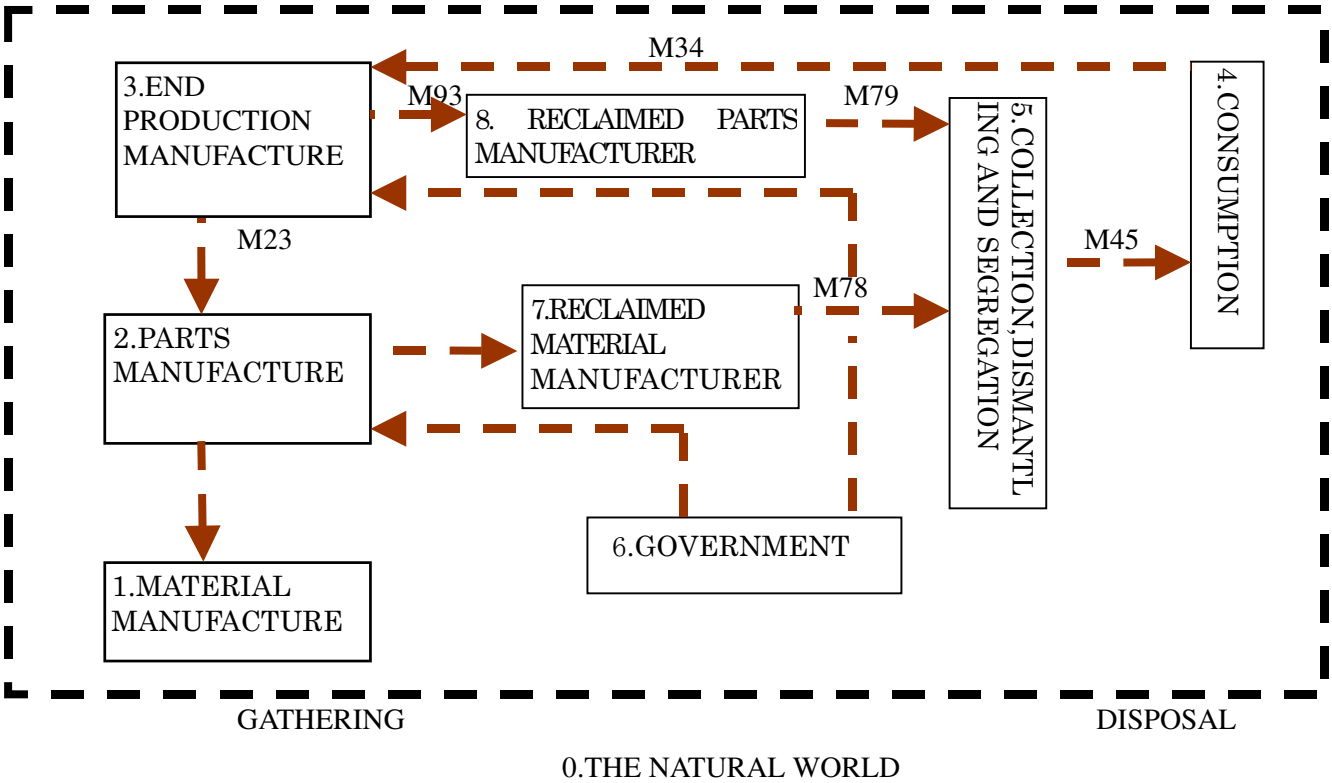

Figure 5 The money flow in recycling-oriented manufacturing systems

6. The information flow of recycling-oriented manufacturing systems

In the recycling-oriented manufacturing systems, basically information flows in the reverse direction of money as same as the mass production, mass consumption, and mass disposal. However, the part of the government becomes more important in this case, because the government decides how much money is investigated in each part and material. When the government decides the amount of money to a reclaimed part or a weight unit of reclaimed material, the information of the costs and energy consumption on manufacturers, plants, consumers and the information of the estimated amount of materials have to be gathered. In Fig.6 these flows are shown.

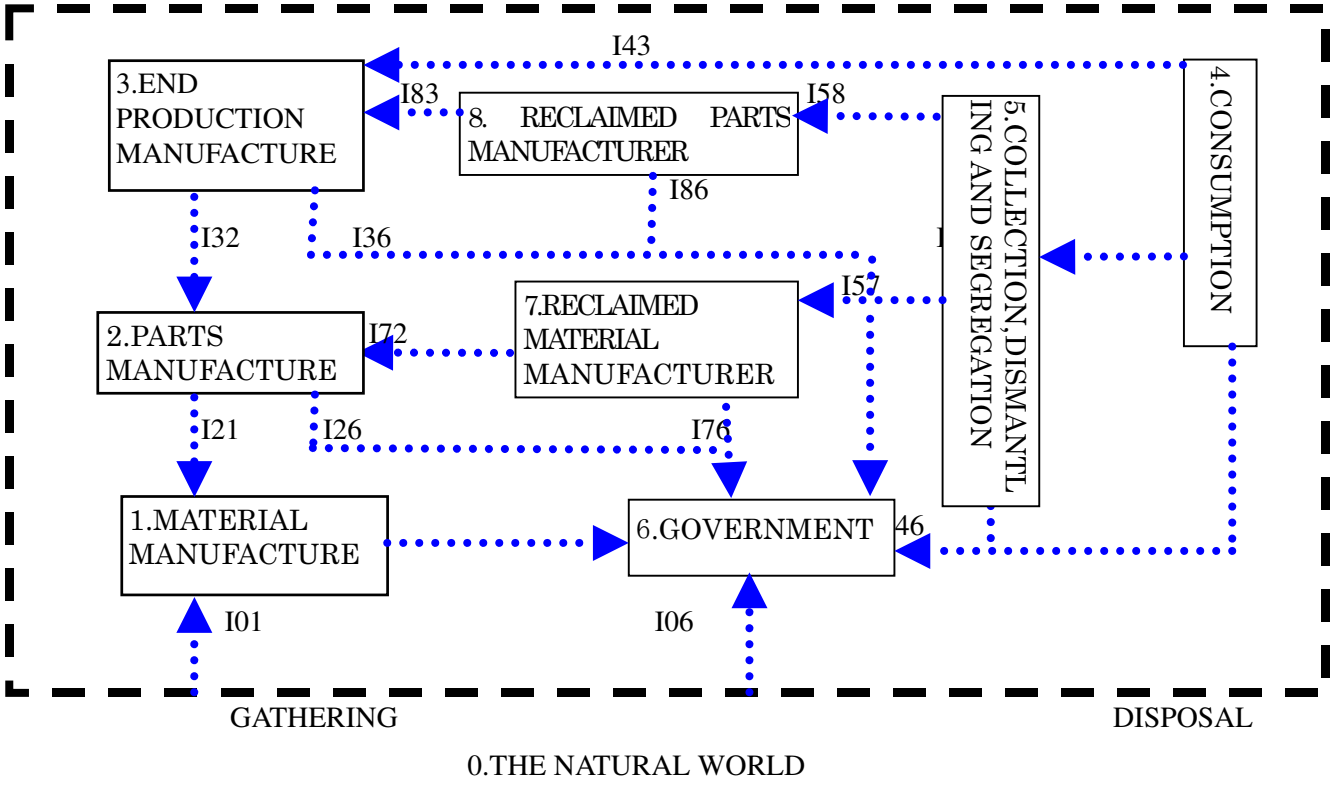

Figure 6. The information flow in recycling-oriented manufacturing systems

7. The optimum flow of material, energy, money, and information in recycling-oriented manufacturing systems; in the case that new products development is left out of consideration.

When new product developments are not considered, the energy consumption at consumers is not changed from the disposal manufacturing systems. Therefore, the difference in energy consumption between the mass disposal manufacturing systems and the recycling-oriented manufacturing systems is calculated by the manufacturing consumption and the transportation consumption. The material recycling ratio should improve towards one hundred percent under a level of energy

consumption where the total entropy on the earth does not increase.

Maximize

$$\left(\sum_{j=1}^{m} W_j + \sum_{k=1}^{l} W_k\right) \Big/ \sum_{i=1}^{n} W_i \tag{1}$$

subject to

$$\sum_{j=1}^{m}(E_{58j} + E_{8j} - E_{83j}) + \sum_{k=1}^{l}(E_{57k} + E_{7k} + E_{72k} + E_{2k} + E_{23k}) + \sum_{h=1}^{n-m-l}(E_{01h} + E_{1h} + E_{12h} + E_{2h} + E_{23h} + E_{50h}) - \sum_{i=1}^{n}(E_{01i} + E_{1i} + E_{12i} + E_{2i} + E_{23i} + E_{50i}) \le A \tag{2}$$

$$\sum_{j=1}^{m}(C_{54j} + C_{85j} + C_{38j} + C_{63j}) + \sum_{k=1}^{l}(C_{54k} + C_{75k} + C_{82k} + C_{62k}) + \sum_{h=1}^{n-m-l}(C_{21h} + C_{32h}) - \sum_{i=1}^{n}(C_{2i} + C_{32i} + C_{65i}) \ge 0 \tag{3}$$

Decision variable i; it means which part should be used, reclaimed parts j, reclaimed material parts k, or virgin parts h.

Where,

i: part

n: number of all kind of parts

j: reclaimed part

m: number of all kind of reclaimed part

k: part made from reclaimed material

l: number of all kind of part made from reclaimed material

W_i: weight of part i

W_j: weight of part j

h: virgin part

A: upper limit of energy consumption for a production, which the recycling-oriented

manufacturing systems can exceeds the mass disposal manufacturing systems by
The meanings of other symbols are written in Fig.1, Fig.2, and Fig.3.

When we look at these equations from another point-of-view, we can say that this problem is for how to find the best part for each kind of part from reclaimed parts, parts made from reclaimed material, or virgin parts. If the government intends that the recycling ratio of parts should be close to one hundred percent, reclaimed parts must be selected. In this case, if the government has enough budget, a part that consumes less energy on the manufacturing process must be selected, and the government should shoulder the cost difference between the selected part and the lowest cost part.

If we intend to grow without new products, the recycling speed has to be accelerated. However, the energy consumption will be increased by the speed up of material flow. The authors believe the development of new products, which are small and light, but functional is very important and, of course, the products must be recyclable.

8. Conclusions

As elaborated in this article, green and clean environments are watchwords in the current society. Government-support activities are directed towards making the surroundings cleaner and greener. Many manufacturers are of course tackling the problems positively by themselves. However, there are many contraries to each other in steps. In this article, a model for recycling-oriented manufacturing systems has been proposed, which is for synthetic evaluation, and the flow of material, energy, money, and information associated with the proposed model are discussed. The optimization of the model is discussed with the flows.

References

[1] Ed.M.Gatyson, Recycling, Fuel, and Resource Recovery-Economic and Environment-recovery, New York, Wiley 1984
[2] N.L.Nemerow, Zero Pollution for Industry-Waste Minimization through Industrial Complexes, John Wiley &Sons,1995
[3] P.F.Roan, W.E.Martin: Optimal Production and Reclamation at a Mine Site with an Ecosystem Constraint, J. of Environmental Economics and with an Ecosystem Constraint, J. of Environmental Economics and Management, Vol.30, No.2, pp.189-198, 1996
[4] Ruedi Muller-Wenk, Die Okologische Buchhaltung, Campus Verlag, 1978
[5] R.Welford (ed.), Corporate Environmental Management, Earthscan Publication, 1996