Macroergonomic Approach for Improving the Municipal Waste Management System in Jakarta

Amalia Suzianti, Siti Humaira, and Shabila Anjani

***Abstract*—To solve the complex problem of the waste management system in Jakarta, there needs to be a comprehensive approach to the system. One of the approaches that could be used to solve this problem is the macro-ergonomic approach, where Macro Ergonomic Analysis and Design (MEAD) is one of its methods. Through this approach, it is known that the main problem of this system is human error in disposing waste. Improving rubbish bins is a solution that could help the problem technically, where New Product Development Processes (NPD Processes) is implemented to develop the rubbish bin. The new design of rubbish bin has some additional features that would decrease human error in disposing waste. This paper will discuss the color coding, signs of waste segregation, differentiation in locating disposal holes, different types of container lids, types of trash bag hooks, the swing feature of the bin, and the ideal information media of a rubbish bin.**

***Index Terms*—Recycle bin, MEAD, re-design, macroergonomic, new product development processes.**

I. Introduction

Collecting household disposals and industrial waste is one of the most difficult operational problems faced by local authorities in any large city. This problem is also faced by Jakarta, the capital city of Indonesia. With an increasing number of populations due to the rising number of urbanization every year, Jakarta's waste volume is rapidly increasing. The volume of waste generated in Jakarta could reach up to 6500 tons per day.

To keep the city clean, the government's Cleaning and Landscaping Agency faced some major waste disposal problems, such as public awareness about cleanness, waste-handling facilities, human resources, legacy, periodic targets, and other problems related to open dumping. A solution is needed to overcome this complex problem. This research is done by redesigning the rubbish bin used in Jakarta, as an effective solution for improving Jakarta's waste handling system,

II. Methodology

This research will be using stages of Macro Ergonomic Analysis and Design (MEAD). MEAD is one of the macro ergonomic methods that consist of ten stages used for assessing and improving the work systems [1].

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The authors are with Industrial Engineering Department, Faculty of Engineering, Universitas Indonesia (e-mail: amalia.suzianti@alumni.TU-Berlin.DE, Humaira.siti@gmail.com)

A. Defining the Design Framework of the System, Environment and Organization

The current waste management system in Jakarta is shown in Fig. 1, which consists of input, process, and output.

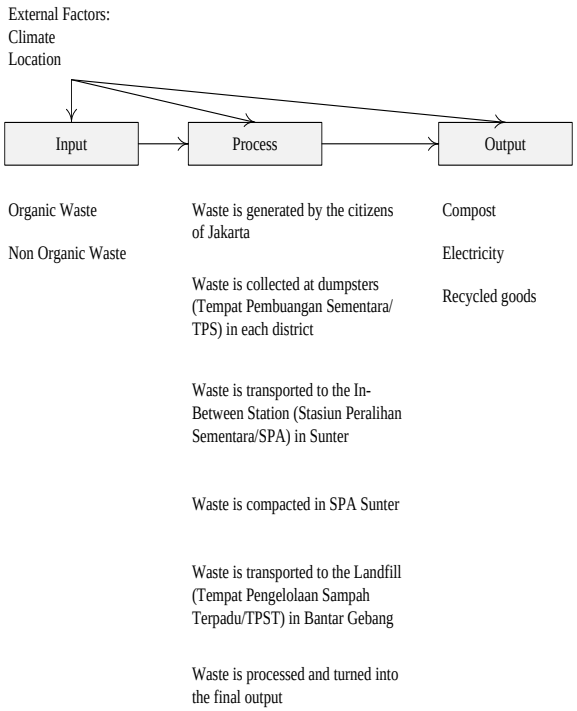

Fig. 1. Waste handling system in Jakarta.

B. Defining the Type and Setting the Performance Expectation of the Work System

It is found that the problems faced by the Cleaning and Landscaping Agency affects the performance of this work system. These problems are as following:

1) Transportation Facilities: This is measured by the calculating the availability rate of transport facilities. Table I describes the detailed condition of transport facilities belonged to Cleaning and Landscaping Agency of Jakarta.
2) Human resource: The current number of workers is much lower than the number of workers 20 years ago, which reached up to 6000 people. This workforce reduction is more on operational workers, such as drivers, garbage collector, and trash sweeper.
3) The total of collected waste: Fig. 2 shows a graph that describes the waste collection from 2005 to 2010. From this graph, it is seen that from 2007 to 2010, there is an increasing number of waste that is not collected

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TABLE I: TRANSPORTATION CONDITION

No.	Type of Transportation	Age of Transportation		Number of units	Capacity (m^3)
		≤15 years	>15 years		
1.	Small Arm Roll	55	75	130	6
2.	Big Arm Roll	79	95	174	10
3.	Small Typer	96	77	173	10
4.	Big Typer	90	102	192	20
5.	Small Compactor	60	13	73	12
6.	Big Compactor	50	5	55	24
7.	Motor Cart	300	0	300	1
	Total	730	367	1097	

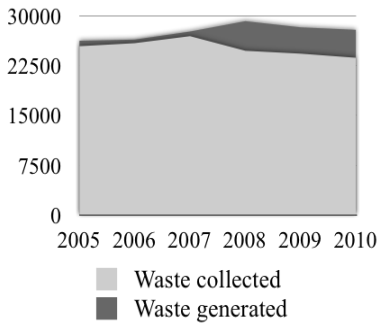

Fig. 2. Numbers of collected waste.

4) Budget: Funding for all the waste management activities only relies on regional budget.
5) Citizen participation: Some citizens are still not able to keep the city clean.
6) Law enforcement: There is no law enforcement for violators due to the lack of human resources that are specifically tasked to enforce cleanliness in the city.

C. Define Operation Units and Work Process

Fig. 3 shows the operation units and the details of the work processes, actors, goals, and facilities used for each operation units.

The operations units of waste management are divided into six units, namely:

1) Public waste
2) Trash collected at TPS
3) Waste transported to the SPA in Sunter
4) Waste compactized in SPA Sunter
5) Waste transported to TPST in Bantar Gebang
6) Waste processed in TPST Bantar Gebangtar Gebang.

D. Identifying Variances

At this stage, all the data is evaluated while the input variance and throughput variance for each unit operation is determined.

E. Creating the Variance Matrix

In this stage, the variances determined in the previous stage are put in the variance matrix, thus it is seen how much the relationship between these variances. Each variance is given weight by the level of urgency. The relationship between variances is weighted by using crisp number (1, 3, 9) which is usually used in conventional Quality Function Deployment (QFD) [2].

Based on matrix in Table II, it is found that the key variance that has the most effect among other variances is "the human error to dispose the waste into the proper bin" because it has the highest value among all variances.

F. Creating the Key-Variance Control Table and Role Network

The Key-Variance Control table of human error in disposing waste into the proper bin is shown in Table III.

III. RESULTS AND DISCUSSION

MEAD method used in data collection is proven to be able to assess work systems starting form macro-scale [3], in this case is waste management system. It also then suggests an effective solution that could be done in micro-scale, which in this case is redesigning the rubbish bin. The stages in NPD Processes [4] assures that the new design of the rubbish bin is effective and innovative, which also solves the needs of Citizens in Jakarta

The rubbish bin design follows the prevailing standards in Indonesia [5] and is modified according to other existing development done in other countries [6]. The design of the three-dimensional rubbish bin is made using the Autodesk Inventor® 2013 Software.

The re-designed rubbish bin, has three different containers according to its waste group, namely:

1) Organic Waste
2) Recycle Waste
3) Residue

Where it uses a colour code to distinguish each group of waste.

Organic waste is represented by the colour green, recyclable waste is represented in blue, while the residue is represented by the yellow colour. The colours used are basic colors shown in Fig. 4 which also makes it easy to distinguish one another.

The holes of the rubbish bins are also different according to its waste segregation (Fig. 5). The organic waste container has a semicircular hole, the recyclable waste container has an oval-shaped hole, while the residue waste container has rectangular-shaped hole. On the upper side of the rubbish bin could be seen signs that represent waste segregation. Fig. 6 clearly shows signs used in this rubbish bin.

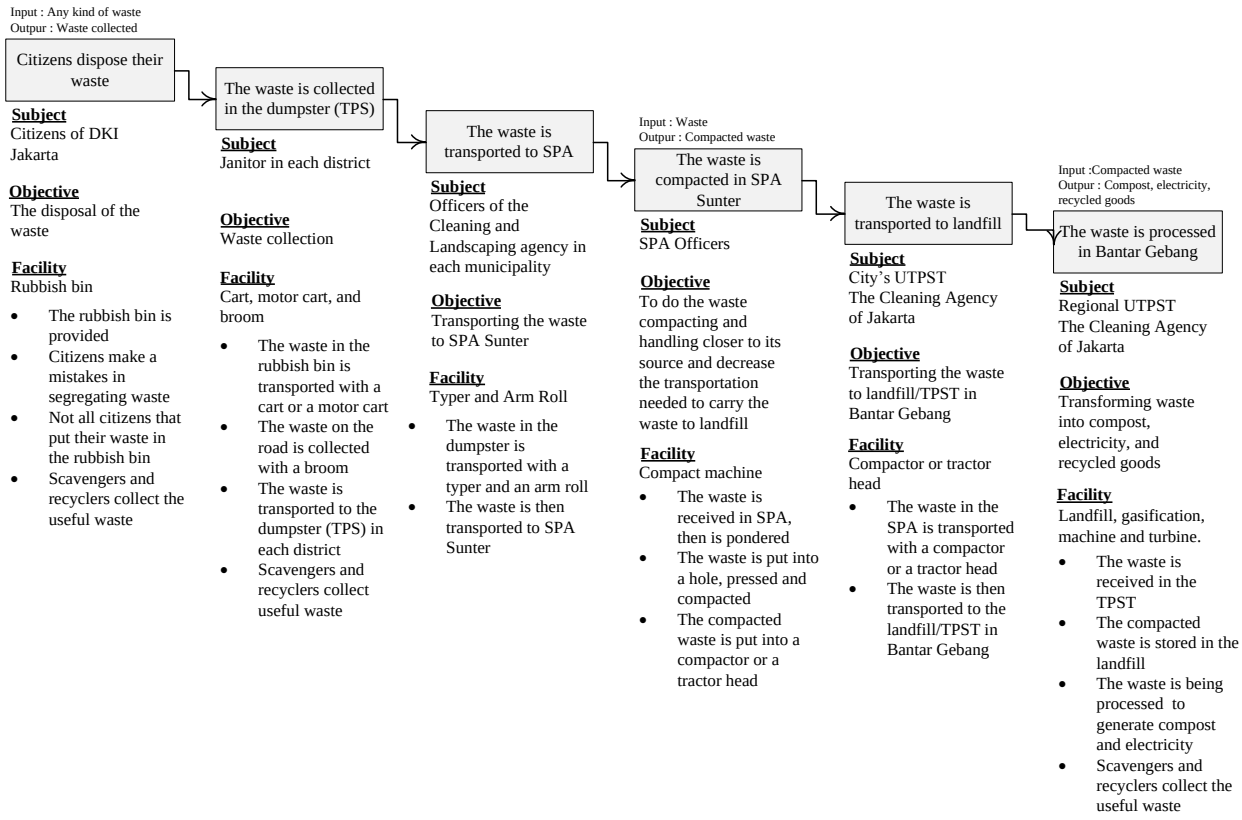

Fig. 3. The Flow process of waste handling system in Jakarta.

TABLE II: VARIANCE MATRIX

	Variance	Weight	a	b	c	d	e	f	g	h	i	j	k	l	m	n	Total
a	Failure in waste segregation	12.5%		⊙	•	•	O		•	O	O			O	O		3.375
b	Damage waste quality due to failure in waste segregation	10.0%	⊙				⊙										1.8
c	The waste is not disposed in the bin	12.5%	•			⊙	•										1.375
d	Not all waste is collected	10.0%	•		⊙		•										1.1
e	The waste disposal is not following the segregation shown in the provided bin	7.5%	O	⊙	•	•				•	•			•	O		1.5
f	Delay in waste collection	5.0%							⊙								0.45
g	Cumulating amount of waste in TPS	5.0%	•					⊙									0.5
h	The waste that comes to the SPA has not being segregated	5.0%	O				•				⊙			O	O		0.95
i	Non-organic waste is compacted	5.0%	O				•			⊙				⊙	O		1.25
j	Not all waste that come to TPST is compacted	5.0%											⊙			O	0.6
k	The processing capacity is lower than the amount of waste generated	7.5%										⊙				⊙	1.35
l	Scavengers could not segregate the compacted waste	5.0%	O				•			O	⊙				⊙		1.25
m	Non-organic waste is processed in GALFAD system	2.5%	O				O			O	O			⊙			0.525
n	Expansion of landfill	7.5%										O	⊙				0.9

Crisp code : •=1 O=3 ⊙=9

TABLE III: KEY-VARIANCE CONTROL

Controlled Key Variance	Controlled Aspects
Key Variance	Failure in waste segregation
Operation Unit	Citizens whom dispose their waste
Responsible Party	Citizens of Jakarta obeying the regulations made by the Cleaning and Landscaping Agency of Jakarta with other private parties.
Control Task	Education and 3R campaign
Technical Support	Rubbish bin
Social Support	3R community

Fig. 4. Design of rubbish bin.

Fig. 5. Differentiations in holes and color.

Fig. 6. Top view of rubbish bin.

Each container is equipped with lids (Fig. 7) that consist of two parts that could be folded twice. The function of these lids are to keep trash inside the container, to keep the waste safe from from outside objects and also to prevent an unpleasant smell outside the container.

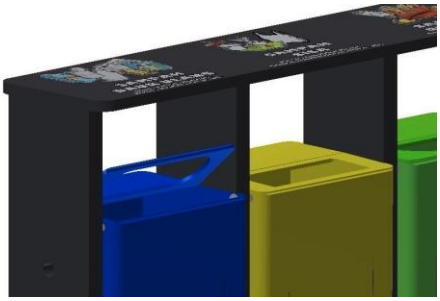

Fig. 7. Lids in containers.

The swing feature of this bin (Fig. 8) is an additional feature to facilitate in collecting garbage.

Fig. 8. Swing feature in container.

This bin is equipped with a plastic bag to make it easier for operator to gather and collect garbage. Therefore, the bin is equipped with a hook (Fig. 9) on the inside to make it easy to hook the trash bag in position.

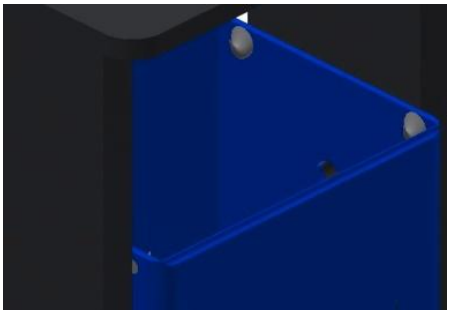

Fig. 9. Hooks inside the container.

In addition, the front of the container could be used as an educational media and also for advertising. Advertisements, posters, campaign media, and others signs could be put on the side of the rubbish bin shown in Fig. 10.

Fig. 10. Front view of rubbish bin.

The container and the lid of this rubbish bin is designed to use High Density Polyethylene (HDPE), while the main frame is designed to use cast iron. HDPE is chosen as trash containers because it is light, strong, durable, and also recyclable.

IV. Conclusion

The habit of the citizen of Jakarta is the major cause of the waste handling system. This is because the citizens of Jakarta are not able to put their garbage in the proper places. One of the solutions for this problem is by improving its technical support, in this case the rubbish bin. Using the Stage-Gate Model, a new improved rubbish bin is made to solve the needs of Jakarta. With some additional features, such as the color coding, signs of waste segregation, differentiation in locating disposal holes, different types of container lids, types of trash bag hooks, the swing feature of the bin, and the ideal information media of a rubbish bin, this re-designed rubbish bin is suitable for improving the municipal waste management system in Jakarta

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Amalia Suzianti is a senior researcher in the Department of Industrial Engineering, Universitas Indonesia. She holds a PhD in Innovation System Design from TU Berlin, Germany and University of Luxembourg, and a Master of Science in Technology and Innovation Management from BTU Cottbus, Germany.

Prior joining Universitas Indonesia, she has acquired international academic and professional work experiences, mainly in Europe, Asia and Latin America. Her research interests lies in the fields of Technology and Innovation Management, Technology Policy, and New Product Development. She is also a member of Product Development and Management Association (PDMA) and Design Research Society (DS).

Dr. Amalia Suzianti's papers have been presented in various international conferences in Germany, Switzerland, UK, and Argentina. Currently, she contributes actively in preparing community engagement research projects based on technology and innovation methodologies.