Journal of Applied Mechanical Engineering

OPEN ACCESS Freely available online

Research Article

Application of Six Sigma Tools for Improvement of Secretion Process in Excessive Waste

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ABSTRACT

The increasing amount of solid waste arising from municipalities and other sources and its consequent segregation and disposal of waste has been one of the major environmental problems the segregation process of these solid waste results with an increasing of number of various solid waste management, often with mutually conflicting objectives. This paper discuss the effective usage material handling while recycling and segregation of solid waste in municipality that is followed by a decision on the implementing measures, with help of industrial concept called six sigma particularly the cause and effect diagram tool and extend simulation software in the analysis phase of DMAIC approach that finding the root cause of this process and loses in the segregation of waste can be minimized by implementing the proposed techniques by this the efficiency of the plant will be increased.

Keywords: Waste segregation; Waste recycling; Material handling system

INTRODUCTION

In Indian scenario, mixed solid waste disposal is a major issue. People lack awareness about plastics utilization and its disposal. The Tamil Nadu government build system for handling and disposal of MSW (municipality solid waste) and make awareness about disposal of waste. But this process cannot achieve 100%, due to population growth and improper disposal of waste**.** In Tamil Nadu, totally seven region are for segregation of MSW. Madurai Municipality Corporation has a system of segregation of MSW plant and bio-fertilizer production plant placed at Avaniyapuram.

The Madurai city has a population of 2,017,865 in 2016. Total area of this plant is 200 acre and daily collection of waste is around 600 to 650 tonnes. At seasonal time it can vary up to 700 tonnes per day. Segregation of mixed solid waste is around 300 tonnes and production of fertilizer from these wastes around 50 tonnes per day. They have two trammel machines for segregation purpose and totally 30 labours work in this plant (Figure 1).

The process flow which occurs in MSW:

Different types of separation methods of waste plastics include

- Manual sorting,
- Solvent separation,
- Flotation separation,
- Static density separation,
- Electrostatic separation and
- Hydro cyclonic separation technology, etc.

PROBLEM DESCRIPTION

From the analysis the movement of waste from tipping yard to conveyor system takes more time and distance. Initially the waste is handled by earth movers which take more time for capturing and feeding the waste to conveyor belt. Manual sorting of ferrous

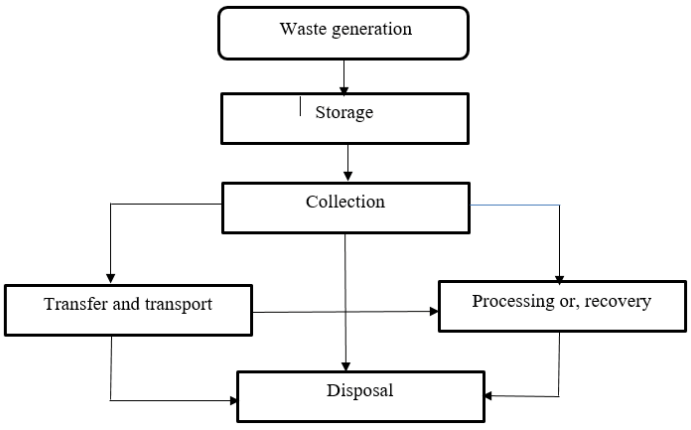

Figure 1: Flow chart.

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Received: May 26, 2020, **Accepted:** July 29, 2020, **Published:** August 05, 2020

Citation: Shunmathi M, Tamilarasan A (2020) Application of Six Sigma Tools for Improvement of Secretion Process in Excessive Waste. J Appl Mech Eng. 9:331. doi: 10.35248/2168-9873.20.9.331

and non-ferrous material is done, sometimes labour would not see these materials and may be skipped this occurs frequently. So that rate of sorting level is not up to the mark [1,2]. The main objective is to increase the existing segregation rate occurring in the plant and reduce the delay time of waste transfer. In this work done by effective separation of plastics and other wastes which leads to minimum land fillings. To increase regular use or recycle of segregated materials and manage the wastage produced day-by-day.

PROPOSED METHODOLOGY

The solution to the problem of the solid waste segregation is inadequate when considering sorting of waste. This is due to certain factor like material handling system, labour's working pattern. To increase the total ton of waste segregated per day. Hence direct land filling will be minimized and also Bio-fertilizer production level will be increased (Figures 2 and 3).

Research demo

It is shown in Table 1.

Measure phase

The Measure Phase is the second phase of the Six Sigma "Define, Measure, Analyse, Improve, and Control", or DMAIC, model. The goal of the Measure phase of a Six Sigma DMAIC project is to get as much information as possible on the current process so as to fully understand both how it works and how well it works. In this phase, a snapshot of the existing processes is taken using data analysis. The current system effectiveness is measured using a variety of metrics. All of the data captured will serve as a baseline to compare later data with the baseline. This measure phase consists of,

Figure 2: Manual sorting.

Figure 3: Segregation plant inside view.

1. Data Collection plan
2. Work study

In this phase, the relevant data about segregation plant is collected which descried that daily collection of waste and quantity of waste sorted per day and how much time taken for each activities (Table 2).

The major O&M cost of components include following (Figure 4);

- Salaries for operation and maintenance, administration, security
- Electricity bill and water bill
- Fuel and oil consumption
- Equipment and facility maintenance
- Supplies
- Residual and bio-degradable waste
- Facility depreciation (Figure 5)

Source of solid waste generation

It is shown in Table 3 and Figure 6.

Collection and sorting of MSW

Quantity of solid wastes produced per day

The rate per person is estimated at 0.4 kg/person/day.

$$SWp=Pop \times Pcp$$

$$=1,875,000 \text{ inhab} \times 0.4 \text{ kg/day}$$

$$=750,000 \text{ kg/day}$$

Pop=Urban population (person)

Pcp=Per capita production (kg/person/day)

Quantity of sw collected/day

$$SWc=SWp \times Css$$

$$=750,000 \text{ kg/day} \times 0.80$$

$$=600,000 \text{ kg/day}$$

SWp=Quantity of solid wastes produced per day

SWc=Quantity of solid wastes collected (kg/day)

Css=Collection service coverage 80% of the population

Quantity of sw collected/year

$$SWc \times 365 \text{ days/year} = 600,000 \text{ kg/day} \times 365 \text{ days/year}$$

$$=219,000 \text{ tons/year}$$

The landfill operates seven days a week, how much refuse should be disposed of each workday

$$SWd=(7 \times 320)/7$$

$$=340 \text{tons/day}$$

Quantity of sw sorted/day,

$$SWs=SWpc \times Css$$

$$=400 \times 0.70$$

Table 1: Research demo.

Industry Name	Solid waste segregation plant- Vellaikal (Avaniyapuram)		
Title	Segregation Process Improvement On Mixed Solid Waste through six sigma		
Project description	The process of sorting is the major issue in municipality corporation therefore by applying six sigma improvement methodologies, increasing the rate of segregation of waste and thereby reducing the direct landfills.		
Prepared by	Tamilarasan N, Shunmathi M		
Project objective	1.To reduce the delay time of material handling system in forward and back movement action(90 sec from 125 sec)		
	2.To reduce the waiting time in manual sorting (5 sec from 35 sec)		
Scope	The scope is to improve the rate of segregation and it does not deal with the land fill or in depth details of the incoming waste.		
Statement	1. Improvement in segregation process.		
	2. Increase in level sorting of waste by 79 Tonnes.		
Source of the project	Information and Data collected from plant, staff and employees		
Roles and responsibilities	**Name**	**Designation in company**	**Role in project**
	N Tamilarasan	Student	Process owner
	P Ramasamy	Assistant engineer	Environmental expert
	G Kannan	Supervisor	Coordinator
Project milestone	Phase	From	To
	Define	25-june'17	15-july'17
	Measure	15-july'17	20-aug'17
	Analyze	20-aug'17	18-sep'17
	Improve	18-sep'17	03-oct'17
	Control	03-oct'17	07-oct'17

Table 2: Collection & sorting of waste.

Year	Generation of MSW	Sorting Ton/yr.	Land Filling/yr.	Open Firing
2000-2012	-	-	-	Yes
2013	300-400	200-220	75	No
2014	400-450	230-250	50	No
2015	500-550	250-280	20	No
2016	500-600	280-300	10	No

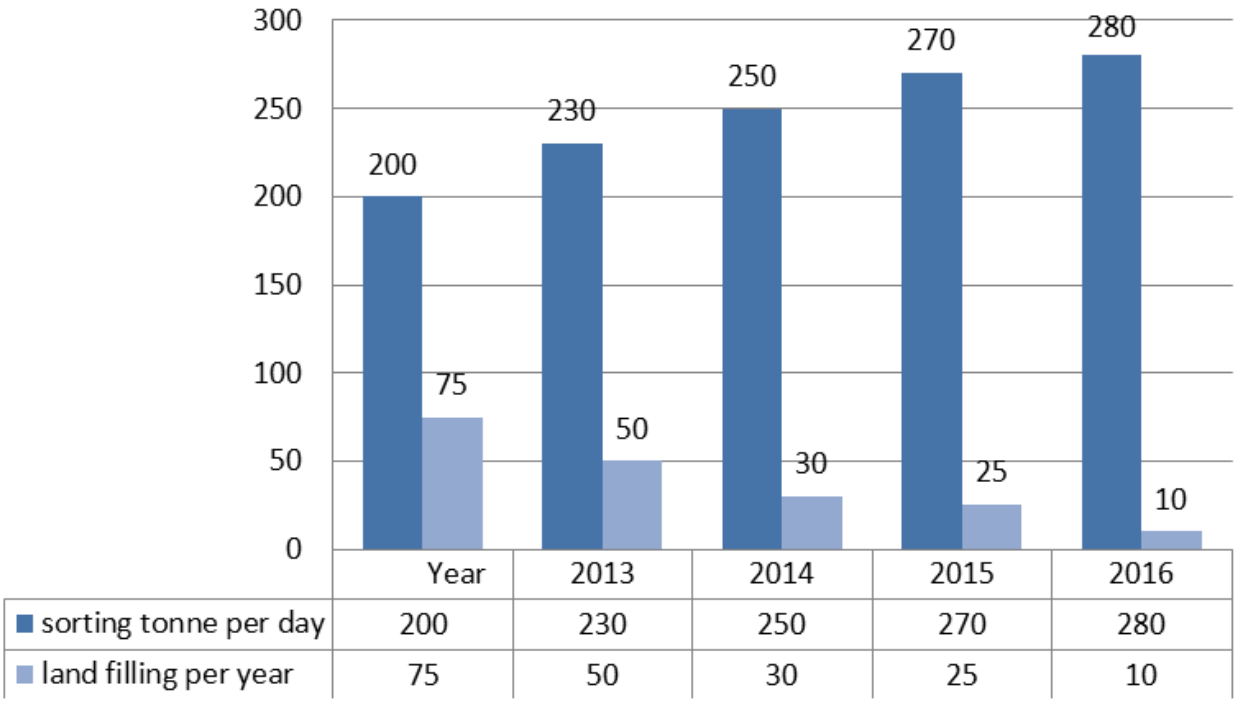

Figure 4: Comparision of sorting waste *vs.* land fill.

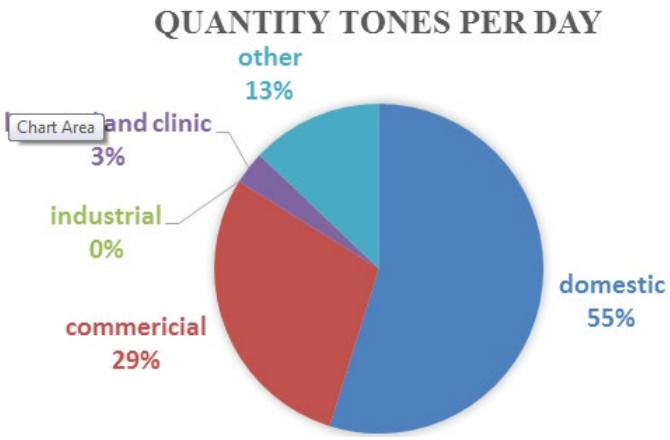

Figure 5: Quantity of tones per day.

Table 3: Solid waste generation.

S. No	Source of waste generation	Quantity tonnes per day
1	Domestic	340
2	Commercial	180
3	Industrial	0
4	Hospital and clinic	20
5	other	80

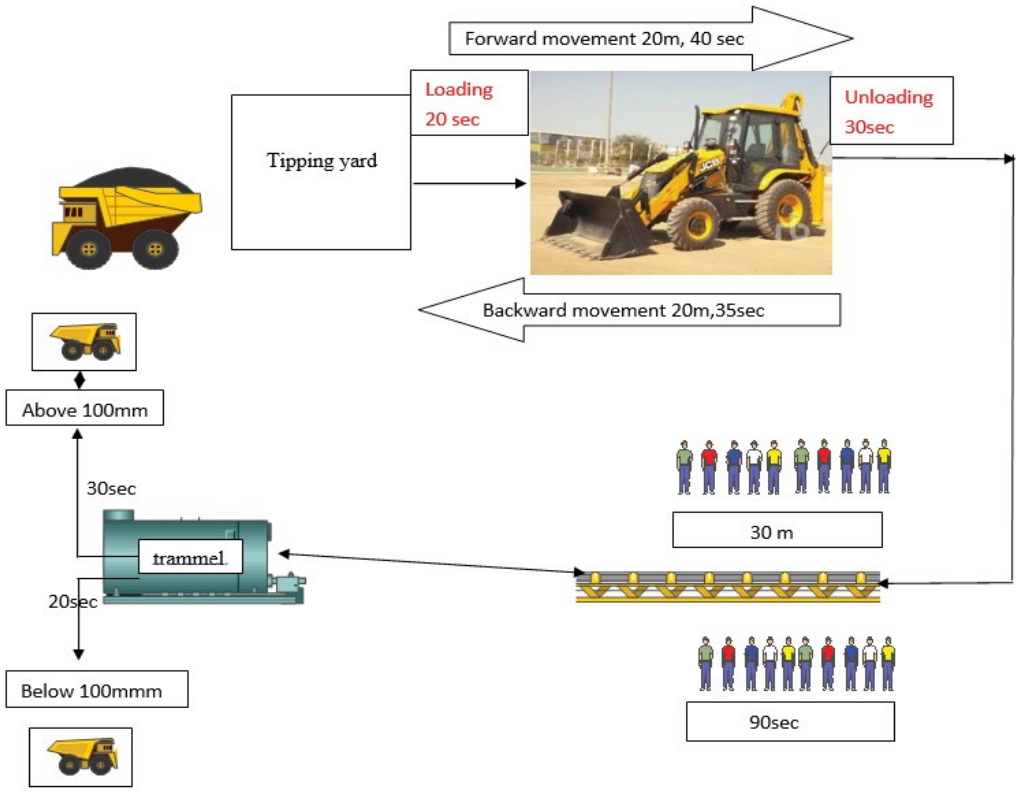

Figure 6: Detailed process flow.

=280 tones/day

SWpc=Quantity of SW sorting capacity/day

Css=Sorting service coverage 70% of the waste

Quantity of sw sorted/year,

=SWs × 365 days/year

=280tones/day × 365 days/year

=102,200 tones /year

Efficiency of this plant presently,

=Output of sorting waste/Input of collected wasted

=(280/400) × 100

=70% (Table 4).

Process flow

Classification based upon two type of process flow chart used as shown in given below

1. Machine type process flow chart
2. Man type process flow chart

By this activity, we can find out non-value added time during this operation.

Machine type process flow chart:

1. The earth mover's used to transfer the waste from tipping yard to conveyor system.
2. Forward and backward movement action is done by earth movers and it is take more time.
3. The earth movers unable to feed the wastes constantly to conveyor system with-out lagging [3-7].

Man type process flow chart:

- Initially labour would wait for segregating.
- Labour performs the work with two hand motion (Table 5).

No of cycle/day=working time per day (in minutes)/2.08 minutes per cycle

= 4 8 0 / 2 . 0 8

=230 cycle/day (Figure 7).

Present method process flow chart

It is shown is Figures 8 and 9.

Analysing phase

The purpose of this phase is to identify, validate and select root cause for elimination. A larger number of potential root cause of the project problem identified via root cause analysis like fish bone diagram (C&E). The top 3 root cause is selected and which is to be worked on. Here the cause is assigned as X's and effect assigned as Y's.

A data collection plan is created and data collected to establish the relative contribution of each root cause to the project metric Y. this process is repeated until valid root cause is identified. Within six sigma, often complex analysis tools are used.

This analyse phase consist of,

1. Basic data analysis,
2. Process analysis,
3. Root cause analysis.

For the first step phase of the project the basic data analysis is done and root cause analysis is done for manual cause only using the appropriate tools which are as follows [8-10].

Alternative method to transfer the waste

From the analysis it is evident that the bottleneck for the process is with the material handling system.

Overhead crane systems: To be specific the earth movers which transfer waste from tipping yard to the conveyor system. Due to the delay in this movement the labours have to wait for about 35 seconds per cycle (Figure 10).

- Overhead crane system

Improvement phase: The goal of the DMAIC Improve phase is to identify a solution to the problem that the project aims to address. This involves brainstorming potential solutions, selection solutions to test and evaluating the results of the implemented solutions.

Improvement stage:

Existed Model:

It is shown in Figure 11.

Capacity: 1.5 Ton.

Distance travelled for loading: 3 mtrs

Spillage: 0.37 Ton (20% of capacity)

In existed design the JCB open grab model bucket is used. The total capacity of bucket is 1.5 Ton, in this design it has some

Table 4: Worker's sorting of waste % per day.

Material	Average kg/person/day	Range kg/person/day
Paper	0.5	0.5-1
Metals	0.2	0.1-0.3
Glass	2	1.5-3
Plastics	2	1.5-3
Non-metals	0.1	0.1-0.2

Table 5: Earth mover's operation time.

S. No	Criteria	Present process
1	No of movements	230 cycle/day
2	Forward movement	2.5 hours/day
3	Backward movement	2.2 hours/day
4	Unloading	2.2 hours/day
5	Loading	1.3 hours/day
6	Segregation	280 tonnes/day (8 hrs)
6	Labor waiting time	135 minutes per day

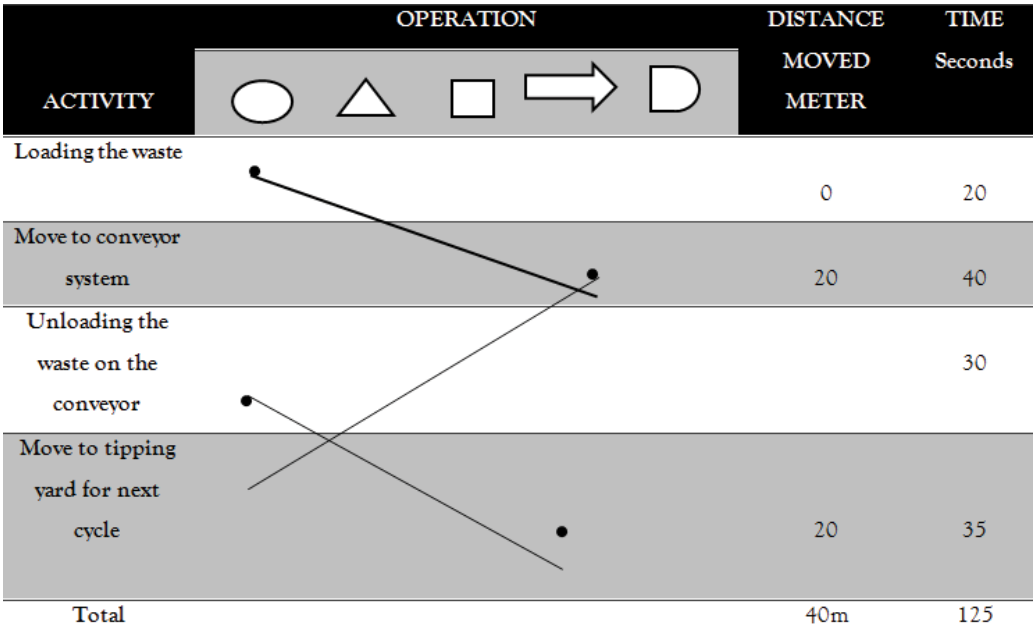

Figure 7: Machine type process flow chart.

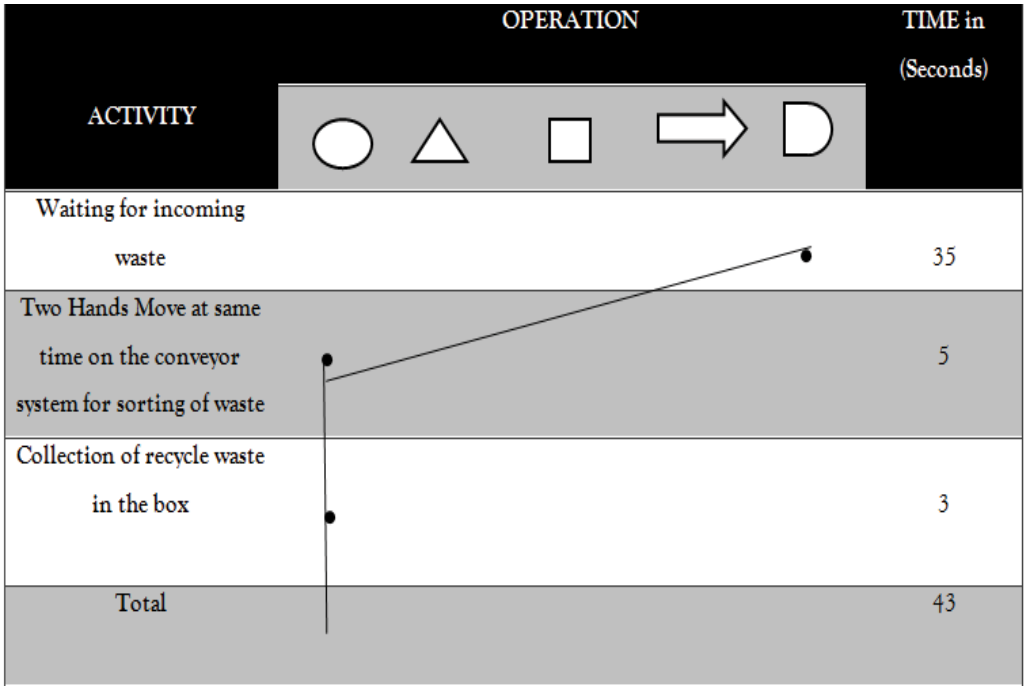

Figure 8: Man type process flow chart.

disadvantage like material spillage, low consumption of materials and the main drawback is that the vehicle has to move about 3 meters for loading the bucket and it takes around 35 seconds per cycle which is a non-value added activity. In this existed design 0.37 Ton (i.e., 20% of total capacity) is spilled, by using this design the movement of machine get higher.

Modified closed garb bucket

It is shown in Figure 12.

Capacity: 2 Ton

Distance travelled for loading: 2.3 meter

Spillage: 0.1Ton (5% of 2 Ton)

In proposed design the JCB closed grab model bucket is used. The total capacity of bucket is 2 Ton, in this design it has advantage like less material spillage, high consumption of materials. In this proposed design 0.05 Ton (i.e., 2.5% of total capacity) is spilled, by using this design the movement of machine get lower.

RESULTS AND DISCUSSION

Simulation results

Extends (formerly known as Extend) is a simulation program for modelling discrete event, continuous, agent-based, and discrete rate processes.

There are four Extend Sim packages:

- CP for continuous processes;

Figure 9: Overhead crane system.

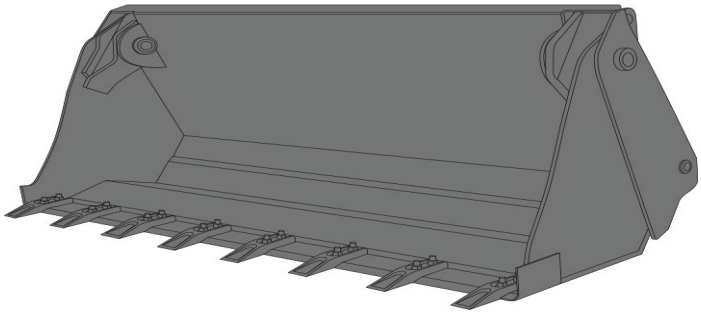

Figure 10: Existed model.

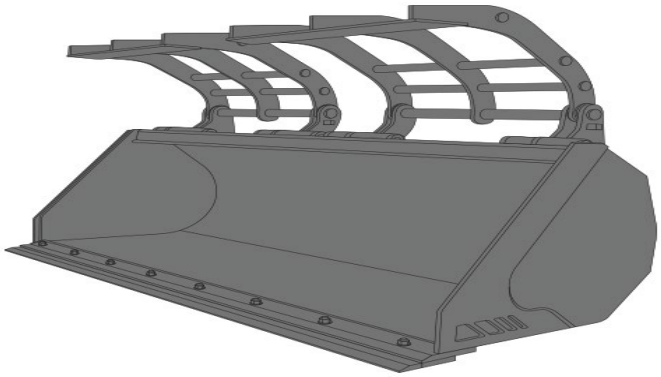

Figure 11: Modified closed garb bucket.

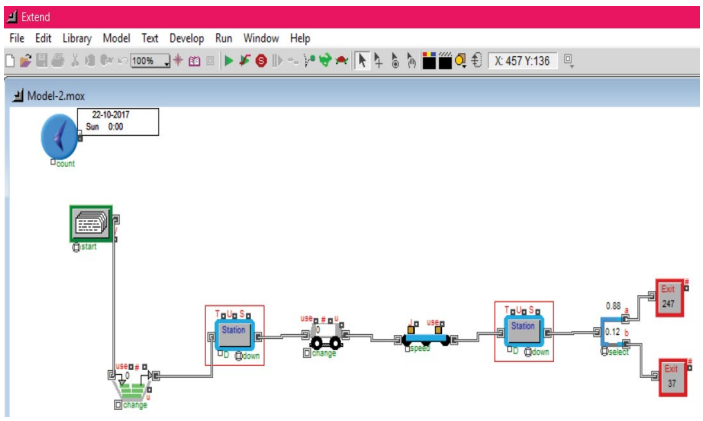

Figure 12: Proposed layout

- OR (operations research) which adds discrete event;
- AT (advanced technology) which adds discrete rate, a number of advanced modelling features, and

Stat::Fit for statistical distribution fitting; and Suite which adds 3D animation [11-13].

Proposed layout-extend sim software

It is shown in Figure 13.

Output

Extend Dialog Report - 7-10-2017 21:32:00

Run#0

Activities

Station Block Number

Input parameters:

Final delay=60

Down connector value is duration

Delay=seconds

Last Delay Used=60 seconds

Do not change animation pictures

Simulation results:

Arrivals=364 Departures=364

Station Block Number 7

Input parameters:

Final delay=90

Down connector value is duration

Delay=seconds

Last Delay Used=90 seconds

Do not change animation pictures

Simulation results:

Arrivals=363 Departures=363

Conveyor Belt Block Number 21

Input parameters:

Capacity=12

Length=98.5

Speed=1.09

Delay=seconds

Last Delay Used=0.12550968399592 seconds

Do not change animation pictures

Simulation results:

Number in = 364 Number out = 364

Executive

Executive Block Number 0

Input parameters:

Simulation stops at end time (timed)

Items to Initially Allocate=1000

Group Size for Additional Item Allocations=1000

Number of Attributes for Each Item=1

Simulation results:

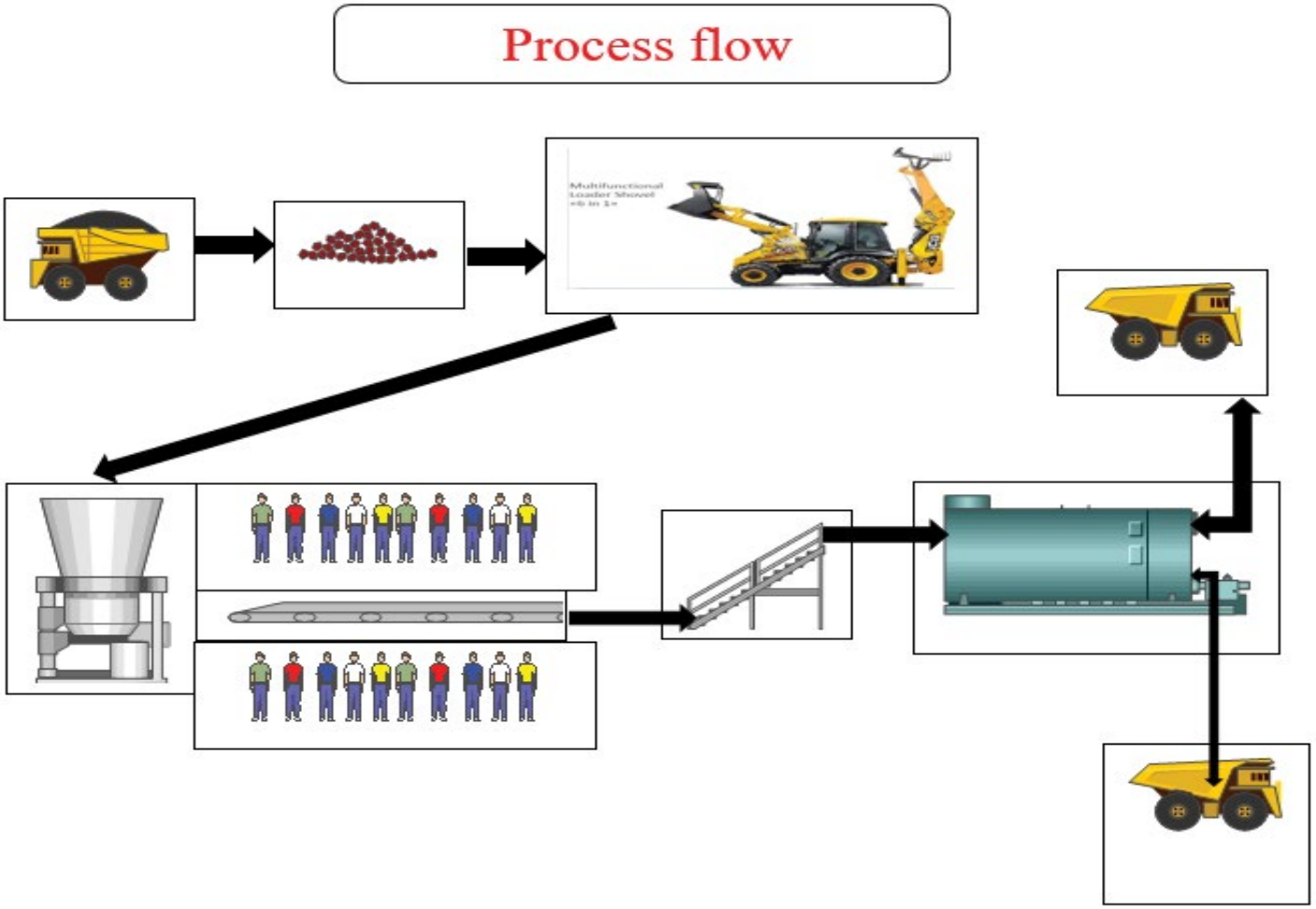

Figure 13: Process flow.

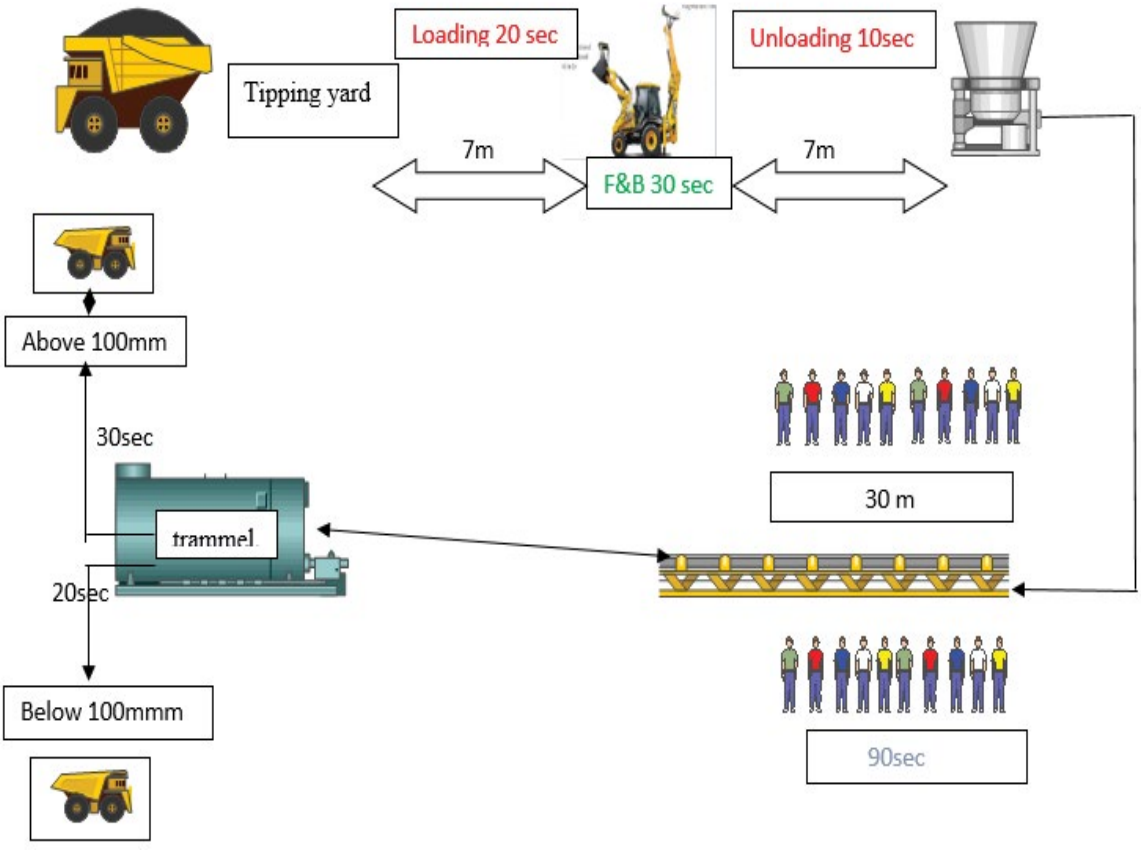

Figure 14: Detailed process flow.

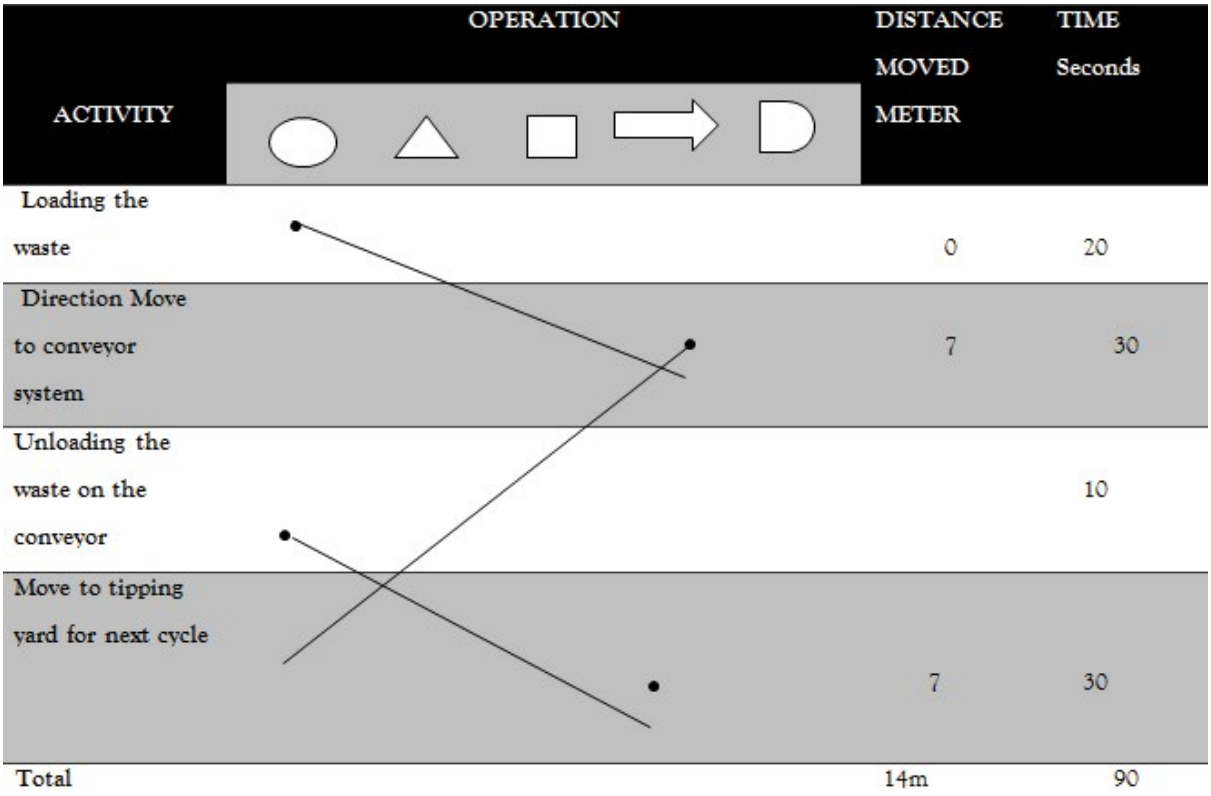

Figure 15: Man type process flow chart.

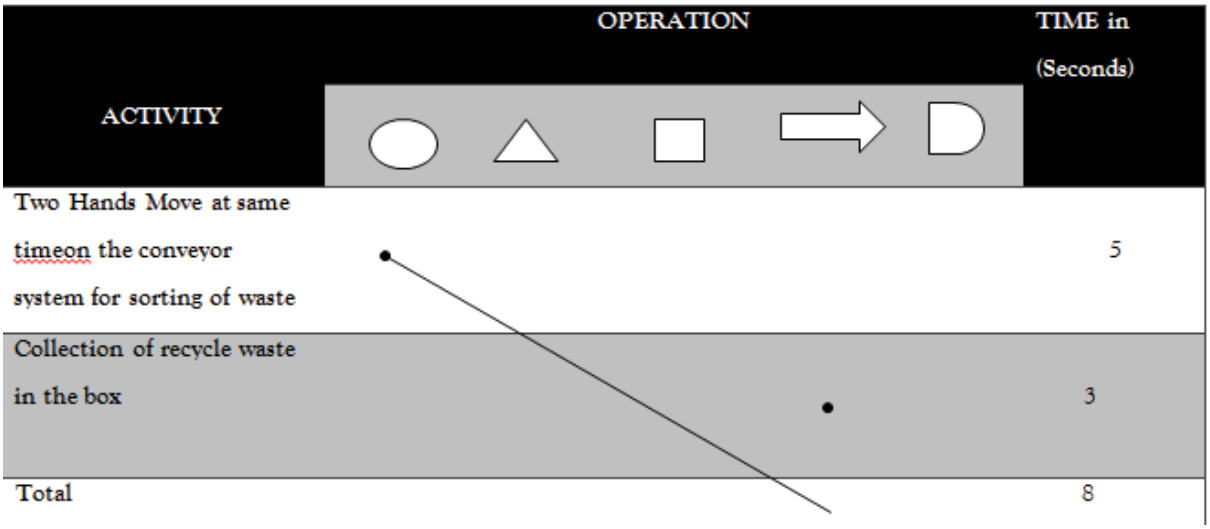

Figure 16: Proposed process operational timing.

Item Rows Allocated=1000

Generators

Program Block Number 29

Input parameters:

Item Animated=Green circle

Simulation results:

Output Time, Value, Priority, Attribute Value

Time	Value	Priority	Attribute:
0.0000000	1.0000000	1.0000000	
400.00000	2.0000000	2.0000000	

Generators resources

Bin Block Number 5

Input parameters:

Initial Available=360

Default Attribute, Value=, Priority=

Strip attributes from incoming items

Final number in use=361, Final Available=0

AGV Block Number 20

Input parameters:

Initial Available=1

Item Appearance=Green circle

Final Available=0

Utilization=1

Routing

Select DE Output Block Number 2

Input parameters:

One of every 0.85 outputs uses lower con

Invalid selects default to top output

Do not change animation pictures

Exit Block Number 8

Simulation Results: Number exited=308

Exit Block Number 9

Simulation Results: Number exited=56 (Figure 14).

Proposed method process chart

Proposed method process chart shown in Figures 15 and 16.

Labour working per day (8 hr-work, single shift)

Actual segregation=280 tonnes/day (8hrs.)

=35 tonnes/hr.

=0.584 tonnes/minutes

Reducing delay time by which segregated

=135 × 0.584

=79 Tonnes (approximately)

Quantity of sw sorted/day,

SWs=SWpc × Css

=400 × 0.89=359 tones/day

SWpc=Quantity of SW sorting capacity/day

Css=Sorting service coverage 89% of the waste

Quantity of sw sorted/year,

=SWs × 365 days/year

=359 tones/day × 365 days/year

=131,108 tones/year

Control phase: The primary objective of the DMAIC Control phase is to ensure that the gains obtained during Improve are maintained long after the project has ended. To that end, it is necessary to standardize and document procedures, make sure all employees are trained and communicate the project's results. In addition, the project team needs to create a plan for ongoing monitoring of the process and for reacting to any problems that arise.

Existing efficiency of this plant

=Output of sorting waste/Input of collected wasted

=(280/400) × 100

=70%

Proposed efficiency of this plant (expected) will be,

=Output of sorting waste/Input of collected wasted

=(359/400) × 100

=89%

On implementing the proposed techniques the efficiency of the plant is expected to increase from 70% to 89% which satisfies our objective.

CONCLUSION

The project titled "*Segregation Process Improvement on Mixed Solid Waste through Six Sigma Tools*" has completed successfully with help of industrial concept called six sigma particularly the cause and effect diagram tool in the analyse phase of DMAIC approach that finding the root cause of this process and also loses of the segregation of waste can be minimized.

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