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Identification and Prioritization of Lean Waste in Higher Education Institutions (HEI): A Proposed Framework

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Abstract: Waste in HEIs is difficult to identify, so identifying and prioritizing waste is challenging. This research aims to develop a framework within which to identify and prioritize waste reduction in HEIs. The novelty of this study is that it analyzes and prioritizes waste in HEI from the perspective of four stakeholders in teaching, research, and community services, as well as supporting activities. The process of waste identification was undertaken via observation and literature review, while prioritization of waste was based on the criticality level of waste (*CLoW*). Determining the criticality level of waste (*CLoW*) consists of two stages: the first stage is calculating waste scores using questionnaires from students, lecturers, and education staff; the second stage is calculating the critical level of waste using a questionnaire from HEI leaders and analyzing it with fuzzy methods. This study identified 59 types of waste and grouped them into eight types: over-production, over-processing, waiting, motion, transportation, inventory, defects, and underutilization talent. Waste occurs in three HEI activities: teaching, research, community service, and supporting activities. The results also show the priority order of waste reduction and proposed improvements to reduce waste. This study offers a practical contribution to the management of HEIs to identify and prioritize waste reduction. The theoretical contribution of this study is that it fills the research gap of waste reduction prioritization in all aspects of HEI activities involving all HEI stakeholders involved in the business process, namely, students, academics, non-academic staff, and HEI leaders.

Keywords: *CLoW*; waste priority; LM education; higher education institution (HEI)

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1. Introduction

Lean manufacturing (LM) has reduced waste and increased efficiency [1]. LM is a method for improving quality and efficiency in manufacturing and service industries [2–4]. Initially, LM was implemented in the automotive industry, then adopted by other industries, including textile, construction, food, medical, electrical and electronics, ceramic, furniture, and service [5,6]. Lean manufacturing is a management philosophy and methodology concerned with the endless pursuit of eliminating waste [7]. Waste is anything that adds cost, but not value, to a product or final customers [8]. Waste was initially recognized in manufacturing as excessive movement, excessive transportation, waiting time, excess inventory, defective products, excess production quantities, and excessive processes.

Quality excellence and process efficiency have become very important in educational institutions [9,10]. Higher education institutions (HEIs) are continuously challenged to meet increasing customer demands; therefore, many have turned to continuous improvement methodologies to leverage organizational resources. So, adopting various frameworks as a mechanism for the assurance of quality education and research outcomes has become an accepted practice [11]. LM is a suitable methodology for improving performance and embedding a continuous improvement culture. LM can be viewed from the perspective of education as a methodology that enables universities, schools, and teachers to effectively and efficiently teach all students by removing or minimizing wastes or losses associated with the educational process [12]. Several higher education institutions (HEI) have used the LM concept to improve the efficiency of scientific activities by eliminating waste and activities that do not add value. HEI faces many challenges and enhances through quality assurance in all its processes [13]. Eliminating waste and increasing efficiency can increase student satisfaction and minimize costs [14] as well as leverage its sustainability [15]. Sustainability in HEI consists of four dimensions: economic, environmental, institutional/educational/political, and social/cultural [16]. The significant positive effect of LM on economic performance indicators (e.g., profitability, profit margin, and return on investment) [17,18]. Meanwhile, based on studies by Lima, et.al [19], LM reduced cost, made better use of resources, increased productivity, decreased processing time, and eliminated documents lost.

Waste in HEI can be grouped into overproduction, over-processing, waiting for time, unnecessary motion, transportation, inventory, defects, and underutilized people [20,21]. Meanwhile, Kang and Manyonge [22] identified the types of waste and classified them based on the perspectives of three stakeholders: students, academics, and non-academic staff. To successfully develop LM, an organization must identify and prioritize the waste to be reduced [23,24]. According to Klein et al. [25], systematic waste reduction is the goal of LM implementation, so prioritizing waste reduction is necessary. Furthermore, systematic identification and waste reduction can increase efficiency, productivity, and competitiveness. In general, industries that always eliminate waste in every process benefit from low inventories of semi-finished goods and finished products, high product quality, increased flexibility, and the ability to meet customer demands and lower operating costs [26]. Several researchers have conducted research to determine waste reduction priorities in the manufacturing [24,26–34] and healthcare sectors [35]. However, less research is conducted on HEI.

Meanwhile, several researchers have determined the ranking of waste in HEI. Kazancoglu and Ozkan-Ozen [20] identified and determined the priority of waste in a business school. In this study, waste priority was determined by a committee of academic staff using the fuzzy decision-making trial and evaluation laboratory (DEMATEL). Meanwhile, Klein et al. [25] used the analytical hierarchy process (AHP) to compare and prioritize waste between the primary and branch campuses. Nonetheless, the weaknesses of this study include the subjectivity of the assessment and the use of the arithmetic average of the assessments made by several directors of the study center [25]. Another study used the waste relationship matrix (WRM) [36], failure mode effect analysis (FMEA), and interpretive structural modeling (ISM) [1] to determine the priority of waste reduction. The limitation of this research is that it only used academic staff as respondents from two faculties, and the identification of waste is only in the teaching and learning process. Further research can be carried out on other processes and involve all stakeholders [1,36]. Another research possibility is the identification of waste in online, offline, and hybrid teaching.

Previous research on waste prioritization in HEIs only involved one stakeholder in one of the activities in HEIs. This article aims to analyze waste and proposes an alternative method to prioritize waste reduction in HEI. Prioritizing waste reduction involves many stakeholders such as students, academic staff, non-academic staff, and HEI leaders. Therefore, the novelty of this study is that it analyzes waste prioritization in HEI from the perspective of four stakeholders in teaching, research, and community services, as well as supporting activities.

The remaining sections of this manuscript are organized as follows: Section 2 is a literature review of waste and LM as well as waste in HEI; Section 3 presents a proposed framework to determine waste reduction priorities in HEI; Section 4 presents results and discussion; and Section 5 presents conclusions.

2. Literature Review

2.1. Waste and Lean Manufacturing

The Japanese manufacturing industry, especially Toyota, developed the LM concept. LM is a waste reduction technique that many authors have suggested. The goals of implementing LM are lower production costs, increased output, and shorter production times [37]. In practice, LM maximizes product value by minimizing waste. LM defines the value of a product/service as what is perceived by the customer [38]. The basic principle of Lean manufacturing (LM) is LM thinking. LM thinking consists of five principles: determining product value based on customer needs, identifying product value streams in the process, uninterrupted value flow, pulling information from consumers (pull system), and pursuing perfection [39]. LM is known as a waste reduction technique. At first, Taichi Ohno [8] grouped waste into seven categories: overproduction, over-processing, waiting, transportation, unnecessary inventory, unnecessary motion, and defects. Furthermore, Liker (2004) added the eighth form of waste—unused employee creativity/talent [20]. The concept of eliminating waste has had a significant impact on various industries.

2.2. Waste in HEI

The application of LM principles in HEI has resulted in significant improvements. The main goal of implementing LM is to eliminate waste. Several HEIs have used the LM concept to improve the efficiency of scientific activities by eliminating waste and activities that do not add value. HEI faces many challenges and must improve quality through quality assurance in all its processes [13]. Some researchers categorize waste in HEI into four general categories, namely, people waste, process waste, information waste, and asset waste [40]. However, most researchers classify waste as transportation waste, inventory, motion, waiting, over-production, over-processing, defects, and the underutilization of people [20,25,36]. There are several wastes in the daily operations of the teaching, research, administration, finance, and human resources in the HEI. Moreover, as opposed to a manufacturing system with tangible results, HEI procedures are less visible, making it more difficult to spot problems as they arise [41]. Table 1 displays examples of waste in manufacturing and HEI.

Table 1. Examples of manufacturing waste and HEI.

Waste	Manufacture	HEI
Over Production	Production over or before demand Large warehouses of finished goods	Producing more than what is currently needed The workload each semester is not balanced An excessive number of academic or administrative units
Over Processing	Doing something that does not add value to the customer Use of more resources than the necessary	Repeat approval Repeat checks Implementation of a new program that is not ready Re-entering data
Waiting	Waiting for the previous process that has not been finished. Lack of material, tools, or information	Waiting for document approval, IT system downtime, and searching for files, books, and documents.
Motion	People or equipment move more than necessary Bad workstation organization	Movement of students and staff Scattered campus locations Excessive movement of information, data, and decision
Transportation	Unnecessary movement of material in the process Inadequate layouts	Movement of materials such as paper, and repeated approvals Too many emails attachments The commonly required material is stored away from the point of use

Table 1. *Cont.*

Waste	Manufacture	HEI
Inventory	All components, WIP, and unprocessed finished products	Unneeded items Documents stored too long Filling out different forms with the same information
Defect	All product defects Inadequate production processes	Data input error, class not used Incomplete documents
Underutilized People (Talent)	Does not use all the capabilities of employees Lack of time for improvement actions	Does not use all the capabilities of employees Not giving assignments according to the ability of students, academics, and non-academic staff Excessive bureaucracy

Source: elaborated by authors based on Douglas et.al. [14], Sanahuja [12], and Klein et.al. [25].

Academic freedom and autonomy are the challenges to LM implementation in the HEI context. The university complexity is increased because the boundaries of academic freedom and diversity are not clear [25].

3. Proposed Framework

HEI stakeholders include academic staff, non-academic staff, students, government, industry, and parents [42]. But in several articles, the ranking of waste in HEI is carried out by the committee [20], the director of the study center [25], and academic staff [1,36],. Other several articles identified students as HEI stakeholders [43–48]. Meanwhile, other researchers involved lecturers and students in their research [49,50], and graduate users [51]. Other research involved students, academic staff, HEI leaders, and graduate users [52]. Waste prioritization must involve stakeholders directly involved in HEI's business processes. This framework aims to determine waste reduction priorities in HEI. Figure 1 shows the several stages in the framework. The process of prioritizing waste involves students, academics, non-academic staff, and heads of study programs. Prioritizing waste is determined based on the criticality level of waste (*CLoW*) value, which is calculated through several stages, as follows.

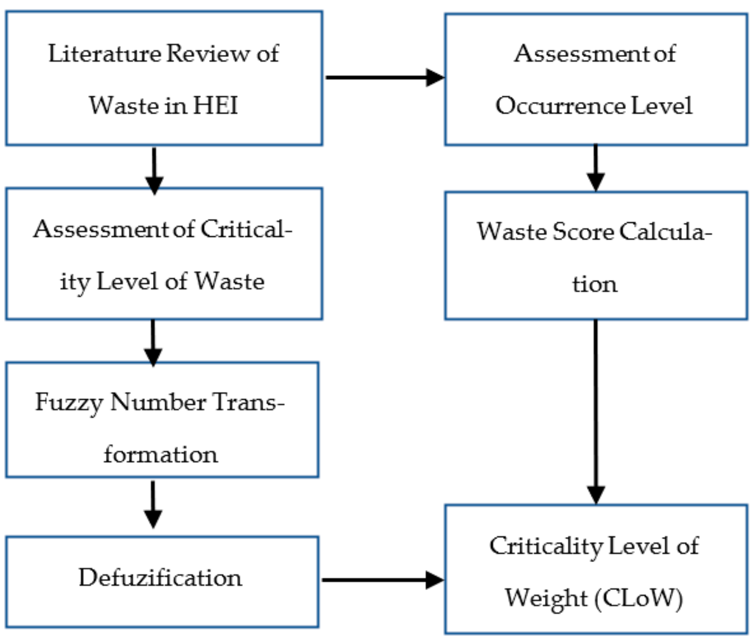

Figure 1. Stages in prioritizing waste.

3.1. Identification of Waste

Identification of waste through literature review and direct observation.

3.2. Assessment of Occurrence Level

Assessment through a questionnaire by students, academics, and non-academic staff. Each respondent assesses the occurrence of every waste by selecting one of the four alternative answers consisting of 1 (never occurs), 2 (rarely occurs), 3 (often occurs), or 4 (very often occurs).

3.3. Waste Score Calculation

Based on the results of the questionnaire, the waste score is calculated and normalized using Equations (1) and (2)

$$S_i = \frac{(1n_{i1} + 2n_{i2} + 3n_{i3} + 4n_{i4})}{n_{i1} + n_{i2} + n_{i3+}n_{i4}} \quad (1)$$

$$NS_i = \frac{S_i}{\sum S_i} \times 100\ \% \quad (2)$$

S_i = waste ith score;
n_{i1} = number of answers Never Occurs of ith waste;
n_{i2} = number of answers Rarely Occurs of ith waste;
n_{i3} = number of answers Often Occurs of ith waste;
n_{i4} = number of answers Very Often Occurs of ith waste;
NS_i = normalized waste ith score

3.4. Assessment of Criticality Scale Waste

The assessment is through a questionnaire filled out by HEI leaders. They assess the criticality scale of each waste using a Likert Scale which consists of a value of 1 (very not critical), 2 (not critical), 3 (quite critical), 4 (critical), or 5 (very critical).

3.5. Fuzzy Number Transformation

Rensis Likert (1932) introduced the Likert scale, widely used in survey research. The popularity of the Likert Scale is due to several things, including its being easy to modify and compile, easily analyzed by statistical methods, and having high reliability. However, on the Likert scale, respondents are forced to choose an option that may be different from their actual choice [53]. Some academics argue that the answers in the Likert Scale are ordinal scale data and that the operations of addition, subtraction, division, and multiplication and the calculation of the mean and standard deviation cannot be done [54]. Due to the limitations, the questionnaire answers were analyzed using the fuzzy method; the Likert scale is converted into a fuzzy number. The fuzzy number used is a triangular fuzzy number (TFN) because it is easy to understand and calculate, and it can be applied in uncertain environments [55].

Calculation of critical scale using the fuzzy method follows the steps below.

3.5.1. Transformation Criticality Scale into Fuzzy Number

Each criticality scale answer is converted into a Triangular Fuzzy Number (TFN). The TFN value consists of the lowest value (l), the middle value (m), and the highest value (u). Table 2 shows Transformation into TFN.

3.5.2. Calculate the Average TFN Critical Scale

The average TFN critical scale for each waste is calculated using Equation (3) [55,56]

$$\check{A}_{javg} = \frac{\sum_{i=1}^{n} \check{A}_j^i}{n} = \frac{(\sum_{i=1}^{n} a_{j1,}^{(i)})(\sum_{i=1}^{n} a_{j2,}^{(i)})(\sum_{i=1}^{n} a_{j3,}^{(i)})}{n} \quad (3)$$

i = 1, 2, . . . , n;
j = 1, 2, . . . , m;
$\breve{A}_{vg}$ = average TFN criticality scale jth waste;
$\breve{A}_j^i$ = TFN criticality scale ith respondent, jth waste;
$a_{j1,}^{(i)}$ = lowest value (l) of $\breve{A}_j^i$;
$a_{j2,}^{(i)}$ = middle value (m) of $\breve{A}_j^i$;
$a_{j3,}^{(i)}$ = highest value (u) of $\breve{A}_j^i$;
N = number of the respondent;
m = the number of waste.

Table 2. Transformation of criticality scale.

Criticality Scale	Likert Scale	Fuzzy Number (l, m, u)
Very Not Critical	1	(1, 1, 2)
Not Critical	2	(1, 2, 3)
Quite Critical	3	(2, 3, 4)
Critical	4	(3, 4, 5)
Very Critical	5	(4, 5, 5)

3.5.3. Defuzzification of TFN

The defuzzification formula for TFN using Equation (4) [56–58].

$$V_{\breve{A}} = \frac{(a_1 + 2a_2 + a_3)}{4} \tag{4}$$

$V_{\breve{A}}$ = the crisp number of $\breve{A}$ TFN (a_1, a_2, a_3).

3.6. Calculate the Criticality Level of Waste (CLoW) Value and Prioritize Waste Reduction

Calculation of the *CLoW* value of each waste using Equation (5).

$$CLoW_i = NS_i \times V_{\breve{A}} \tag{5}$$

The waste that has the largest *CLoW* value is the waste that is prioritized to be reduced (eliminated). Determining waste reduction priorities based on *CLoW* means considering the level of occurrence and criticality of waste and shows that the prioritization of waste reduction involves various stakeholders, namely, students, academics, non-academic staff, and HEI leaders.

4. Result and Discussion

The framework is used at a private university in Indonesia, which was established in 1960. Currently, the university has 22 departments, 1 postgraduate school, a vocational school, engineer professional programs, pharmacist professional programs, nurse professions, teacher professional education, and medical professional education. The university has more than 7000 students and 400 academic staff.

Waste in HEIs is categorized into eight categories of waste, as shown in Table 3. Waste was found in three pillars of the HEI process: teaching, research, and community service, as well as supporting activities.

Table 3. Waste in HEI.

Category	Waste	Code	Author(s)	Process
Over Production	Excessive/repetitive information/announcements	OPR1	[1,14,20,25]	Supporting Activity
	Establishment of unnecessary academic and administrative units	OPR2	[20,25]	Supporting Activity
	Provision of unnecessary facilities	OPR3	[22]	Supporting Activity
	Unbalanced lecture daily schedule	OPR4	[14]	Teaching
	Lecturers print out too many lecture materials, questions, journals, etc.	OPR5	[1]	Teaching
	Too academic staff	OPR6	[1]	Teaching
Over Processing	Repetitive work/tasks	OPC1	[20]	Teaching
	Courses that are too varied	OPC2	[20]	Teaching
	Repeated document checks and approvals	OPC3	[14,22,25]	Supporting Activity
	Meetings with the same topic repeatedly.	OPC4	[1,25]	Supporting Activity
	Repeated entry of the same data	OPC5	[1,22]	Supporting Activity
	Unnecessary or excessive report/task	OPC6	[22]	Supporting Activity
	The lecturer discusses the same topic repeatedly	OPC7	[1]	Teaching
	Long bureaucracy	OPC8	[20]	Supporting Activity
Waiting Time	Course schedules that cause students to wait	WAIT1	[1,20]	Teaching
	Waiting for document approval	WAIT2	[14,22,25]	Supporting Activity
	Waiting for the procurement of goods	WAIT3	[25]	Supporting Activity
	The information system or internet broken down	WAIT4	[14,22,25]	Supporting Activity
	Waiting to search for files, books, or documents	WAIT5	[14]	Teaching
	Awaiting repair of broken facilities	WAIT6	[1]	Teaching
	Long research proposal submission process	WAIT7	[36]	Research
Motion	Moving between classrooms	MOT1	[20]	Teaching
	Equipment movement	MOT2	[20,22,25]	Supporting Activity
	Equipment is stored away from where it is used	MOT3	[22]	Supporting Activity

Table 3. *Cont.*

Category	Waste	Code	Author(s)	Process
Excessive Transportation	Movement of documents or materials	TRP1	[14,20,22]	Supporting Activity
	Bringing lecture materials, books, and teaching equipment to the classroom/laboratory.	TRP2	[20]	Teaching
	Scatter campus location	TRP3	[14,25]	Teaching
	No necessary equipment available in the room/classroom	TRP4	[22]	Supporting Activity
Inventory	Over inventory of material/stationery	INV1	[20]	Supporting Activity
	Inappropriate class capacity	INV2	[20]	Teaching
	Required materials/ equipment not available	INV3	[25]	Supporting Activity
	Lecture/research materials/ equipment not available (journals, laboratory equipment, software)	INV4	[20]	Teaching, Research, and Community Services
	Many similar documents	INV5	[22]	Supporting Activity
	Purchasing materials before they are needed	INV6	[22]	Supporting Activity
	Keeping documents for too long	INV7	[14]	Supporting Activity
Defect	Lost or missed information	DEF1	[20]	Supporting Activity
	Repeated work at the end of term, e.g., remedial, re-correction	DEF2	[20]	Teaching
	Data entry error	DEF3	[14,22,25]	Supporting Activity
	Broken equipment or infrastructure	DEF4	[25]	Supporting Activity
	Unused classrooms	DEF5	[25]	Teaching
	Incomplete documents	DEF6	[22]	Supporting Activity
	Error entering mark	DEF7	[1]	Teaching
Under-utilization Talent	Unused talents/skills	UT1	[14,20]	Supporting Activity
	Knowledge or expertise that is not shared	UT2	[25]	Teaching
	Academic/non-academic staff assignments that are not under their expertise	UT3	[1,14,20,25]	Teaching
	Lack number of research and community service	UT4	[1,25]	Research and Community Services
	Journal databases are rarely used	UT5	[36]	Research and Community Services
	Unabsorbed research budget	UT6	[36]	Research and Community Services
	Unabsorbed community services budget	UT7	[36]	Research and Community Services

A questionnaire was developed to assess the occurrence level of waste displayed in Table 1. The questionnaire can be seen in Table A1 in Appendix A. After evaluating and obtaining permission from the leadership of the university, the questionnaire was distributed to students, academics, and non-academic staff. The questionnaire was distributed offline and online in September–October 2022. Respondents filled in the questionnaire anonymously. Questionnaires were distributed to all academics, and non-academic staff of all departments and work units at HEIs and distributed randomly to the students. Seven hundred fifty respondents, consisting of students, academics, and non-academic staff, assessed waste occurrence. The details are presented in Table 4.

Table 4. Respondent assessment of waste occurrence.

Respondent	Gender	Amount	Percentage
Students	Male	214	39.2
	Female	332	60.8
	Total	546	100
Academic Staff	Male	36	36.73
	Female	62	63.27
	Total	98	100
Non-Academic Staff	Male	46	43.40
	Female	60	66.60
	Total	106	100
Total Number of Respondent		750	

The results of the questionnaire and waste score are displayed in Table 5. Score waste calculation and normalization used Equations (1) and (2). An example calculation of waste excessive/repetitive information/announcement (OPR1) is as follows:

$$S_{OPR1} = \frac{[(1 \times 186) + (2 \times 448) + (3 \times 105) + (4 \times 11)]}{186 + 448 + 105 + 11}$$

$$S_{OPR1} = 1.921$$

$$NS_{OPR1} = \frac{1.921}{(1.921+1.941+1.745+\ldots+2.265)} \times 100\ \% = 1.806.$$

Table 5. Result of the questionnaire and waste score.

Waste	Total Answer				Total	Waste Score	Normalized Waste Score
	1	2	3	4			
OPR1	186	448	105	11	750	1.921	1.806
OPR2	55	109	37	3	204	1.941	1.825
OPR3	265	417	62	6	750	1.745	1.641
OPR4	86	304	216	38	644	2.320	2.181
OPR5	30	54	11	3	98	1.867	1.755
OPR6	55	37	4	2	98	1.520	1.429
OPC1	151	367	182	50	750	2.175	2.044
OPC2	110	262	143	31	546	2.174	2.043
OPC3	132	344	224	50	750	2.256	2.121
OPC4	56	111	28	9	204	1.951	1.834
OPC5	164	339	185	62	750	2.193	2.062

Table 5. *Cont.*

Waste	Total Answer				Total	Waste Score	Normalized Waste Score
	1	2	3	4			
OPC6	152	362	187	49	750	2.177	2.047
OPC7	117	293	112	24	546	2.079	1.954
OPC8	139	324	207	80	750	2.304	2.166
WAIT1	54	218	182	92	546	2.571	2.417
WAIT2	82	271	315	82	750	2.529	2.377
WAIT3	8	46	88	62	204	3.000	2.820
WAIT4	37	210	308	195	750	2.881	2.708
WAIT5	13	105	71	15	204	2.431	2.285
WAIT6	71	318	267	94	750	2.512	2.361
WAIT7	13	59	22	4	98	2.173	2.043
MOT1	20	55	19	4	98	2.071	1.947
MOT2	128	450	139	33	750	2.103	1.976
MOT3	47	122	28	7	204	1.975	1.857
TRP1	37	133	32	2	204	1.995	1.875
TRP2	18	40	26	14	98	2.367	2.225
TRP3	205	313	175	57	750	2.112	1.985
TRP4	194	358	139	59	750	2.084	1.959
INV1	45	126	28	5	204	1.966	1.848
INV2	257	287	76	24	644	1.793	1.686
INV3	10	72	21	3	106	2.160	2.031
INV4	13	44	29	12	98	2.408	2.264
INV5	224	400	106	20	750	1.896	1.782
INV6	50	121	28	5	204	1.941	1.825
INV7	21	86	83	14	204	2.441	2.295
DEF1	115	384	212	39	750	2.233	2.099
DEF2	206	334	85	19	644	1.871	1.759
DEF3	17	138	47	1	203	2.158	2.028
DEF4	70	368	255	57	750	2.399	2.255
DEF5	183	401	136	30	750	2.017	1.896
DEF6	193	435	111	11	750	1.920	1.805
DEF7	22	72	4	0	98	1.816	1.707
UT1	172	384	158	36	750	2.077	1.953
UT2	175	387	155	33	750	2.061	1.938
UT3	26	101	65	12	204	2.309	2.170
UT4	9	49	33	7	98	2.388	2.244
UT5	6	38	40	14	98	2.633	2.475
UT6	12	58	24	4	98	2.204	2.072
UT7	16	44	34	4	98	2.265	2.129

The criticality scale of waste was assessed through a questionnaire by 39 HEI leaders consisting of deans, deputy deans, heads of department, and heads of quality assurance offices. The assessment uses a Likert scale and is transformed into a fuzzy number, as in Table 2. The mean fuzzy number is calculated using Equation (3). To get a single value of the criticality scale, defuzzification is performed using Equation (4). To calculate *CLoW*, we used Equation (5). The average fuzzy number, defuzzification value, and *CLoW* value, as well as the rank of waste, can be seen in Table 6.

Table 6. Average fuzzy number, defuzzification, and *CLoW*.

Waste	Average Fuzzy Number			Defuzzification	Normalized Waste Score	*CLoW*	Rank
	l	m	u				
OPR1	1.85	2.43	3.72	2.604	1.806	4.702	48
OPR2	2.25	3.03	4.05	3.088	1.825	5.635	33
OPR3	2.28	3.03	3.97	3.077	1.641	5.048	46
OPR4	2.51	2.97	4.36	3.205	2.181	6.989	17
OPR5	2.23	2.90	4.08	3.026	1.755	5.311	39
OPR6	2.00	2.49	3.74	2.679	1.429	3.829	49
OPC1	2.56	3.08	4.33	3.263	2.044	6.669	23
OPC2	1.79	2.41	3.62	2.558	2.043	5.226	42
OPC3	2.54	3.05	4.28	3.231	2.121	6.851	20
OPC4	2.31	2.92	4.03	3.045	1.834	5.584	35
OPC5	3.05	3.62	4.64	3.731	2.062	7.691	9
OPC6	2.51	3.08	4.31	3.244	2.047	6.638	24
OPC7	2.10	2.79	4.00	2.923	1.954	5.711	32
OPC8	2.92	3.54	4.49	3.622	2.166	7.843	8
WAIT1	2.23	2.87	4.08	3.013	2.417	7.282	12
WAIT2	2.69	3.26	4.44	3.410	2.377	8.108	6
WAIT3	3.31	3.85	4.87	3.968	2.820	11.189	2
WAIT4	3.51	4.28	4.85	4.231	2.708	11.458	1
WAIT5	2.79	3.31	4.59	3.500	2.285	7.999	7
WAIT6	3.31	3.87	4.85	3.974	2.361	9.384	3
WAIT7	2.56	3.36	4.28	3.391	2.043	6.928	19
MOT1	1.87	2.56	3.79	2.699	1.947	5.254	41
MOT2	1.74	2.49	3.69	2.603	1.976	5.144	44
MOT3	1.97	2.59	3.87	2.756	1.857	5.118	45
TRP1	1.92	2.67	3.82	2.769	1.875	5.193	43
TRP2	1.59	2.36	3.51	2.455	2.225	5.463	38
TRP3	2.33	3.03	4.15	3.135	1.985	6.223	26
TRP4	2.59	3.23	4.28	3.333	1.959	6.529	25
INV1	2.03	2.74	3.95	2.865	1.848	5.294	40
INV2	2.49	3.13	4.28	3.256	1.686	5.490	37
INV3	2.77	3.38	4.51	3.513	2.031	7.133	14
INV4	2.62	3.23	4.41	3.372	2.264	7.632	10
INV5	2.62	3.18	4.41	3.346	1.782	5.963	29
INV6	1.92	2.64	3.82	2.756	1.825	5.029	47

Table 6. *Cont.*

Waste	Average Fuzzy Number			Defuzzification	Normalized Waste Score	*CLoW*	Rank
	l	m	u				
INV7	2.33	3.03	4.21	3.147	2.295	7.222	13
DEF1	2.46	3.13	4.28	3.250	2.099	6.822	21
DEF2	2.41	3.03	4.26	3.179	1.759	5.592	34
DEF3	2.72	3.36	4.44	3.468	2.028	7.033	16
DEF4	3.13	3.51	4.85	3.750	2.255	8.455	4
DEF5	2.31	2.92	4.08	3.058	1.896	5.798	31
DEF6	2.69	3.23	4.49	3.410	1.805	6.154	27
DEF7	2.46	3.18	4.05	3.218	1.707	5.494	36
UT1	2.33	2.82	4.21	3.045	1.953	5.945	30
UT2	2.46	2.92	4.23	3.135	1.938	6.073	28
UT3	2.33	2.97	4.03	3.077	2.170	6.677	22
UT4	2.69	3.23	4.41	3.391	2.244	7.611	11
UT5	2.62	3.18	4.46	3.359	2.475	8.312	5
UT6	2.64	3.21	4.33	3.346	2.072	6.932	18
UT7	2.59	3.21	4.28	3.321	2.129	7.070	15

In this research, waste has been identified in the three pillars of the HEI process: teaching, research, and community Service [59], as well as supporting activities. As seen in Table 3, 59 types of waste have been identified and grouped into eight types: over-production, over-processing, waiting for time, motion, excessive transportation, inventory, defects, and underutilized talent. LM aims to improve efficiency and effectiveness by reducing waste. Furthermore, efficiency and performance improvement will improve quality, and HEIs must work together with all stakeholders [60]. Because of the number of waste in HEI, the priority of waste reduction must be determined. Waste reduction prioritization is based on the criticality level of waste (*CLoW*) value. The *CLoW* calculation consists of two stages: the first stage is calculating the waste score through students, academics, and non-academic staff questionnaires; the second stage is calculating the criticality scale of each type of waste by deans, deputy deans, heads of department, and heads of quality assurance offices. Having four stakeholders, this study represents the population better than the previous studies, which only include one stakeholder [1,20,25,36].

According to the Pareto principle, the first twenty percent or twelve top ranks of the *CLoW* should be prioritized for reduction, as can be seen in Table 7.

Table 7. Waste reduction priority.

No.	Code	Waste	Process
1	WAIT4	The information system or internet broken down	Teaching, Research and Community Services, Supporting Activity
2	WAIT3	Waiting for the procurement of goods	Teaching, Research and Community Services, Supporting Activity
3	WAIT6	Awaiting repair of broken facilities	Teaching, Research and Community Services, Supporting Activity
4	DEF4	Broken equipment or infrastructure	Teaching, Research and Community Services, Supporting Activity

Table 7. *Cont.*

No.	Code	Waste	Process
5	UT5	Journal databases are rarely used	Teaching, Research and Community Services, Supporting Activity
6	WAIT2	Waiting for document approval	Supporting Activity
7	WAIT5	Waiting to search for files, books, or documents	Supporting Activity
8	OPC8	Long bureaucracy	Supporting Activity
9	OPC5	Repeated entry of the same data	Teaching and Supporting Activity
10	INV4	Lecture/research materials/equipment not available (journals, laboratory equipment, software)	Teaching, Research and Community Services, Supporting Activity
11	UT4	Lack number of research and community service	Research and Community Services
12	WAIT1	Course schedules that cause students to wait	Teaching

To reduce the prioritized waste, several activities are proposed, among others:

a. Redesign of university information systems. Table 7 shows the waste that is prioritized to be eliminated is "The information system or internet broke down" (WAIT4). Whereas the utilization of information and communication technology (ICT) is an absolute necessity that must be undertaken and utilized by HEIs. Therefore, every HEI needs a reliable and integrated academic information system. Based on interviews, the current state of the information system includes a lack of data integration between departments and supporting work units; there is still a lot of manual data or documents; the information system network often breaks down. Therefore, the university must improve its information system and transform it into internet-based technology. Information systems integrate all components, such as people, management, business processes, and organizational culture [61]. As likewise argued by M. Akour and M. Alenezi [62], the development of internet-based technology has changed the educational environment and aided HEIs in making the switch to digital learning. The use of information systems is essential and necessary to achieve good university governance [63,64]. Several improvements to the information system that can be made include integrating all academic and non-academic data throughout the university and digitizing all processes and documents. HEI information system improvements are expected to reduce some other waste including waiting to find files, books, or documents (WAIT5), repeated entry of the same data (OPC5), long bureaucracy (OPC8), waiting for document approval (WAIT2), repeated document checks and/or approvals (OPC3);
b. Improvement of procurement and maintenance systems. Effective procurement planning and procurement and maintenance processes will support the smooth running of business processes. Currently, the university does not have an adequate procurement system. This causes the procurement process to take a long time and sometimes the procurement of goods does not match what is needed. Some of the improvements that can be made include establishing a procurement system and increasing the expertise of procurement staff. Improvement of the procurement and maintenance system will reduce waste waiting for the procurement of goods (WAIT3), awaiting repair of broken facilities (WAIT6), and broken equipment or infrastructure (DEF4);
c. International journal subscriptions. For conducting good research, appropriate and up-to-date journal references are required. To obtain the necessary articles, HEI must subscribe to enough appropriate journals. Currently, universities subscribe to journal databases via Science Direct limited to several disciplines. However, research requires interdisciplinary analysis, so the university should subscribe to another

journal database. In addition, academic staff and students can access the database of journals subscribed to by The Directorate General of Higher Education—Ministry of Education and the Cultural Republic of Indonesia and the National Library of Indonesia. It will reduce the lack of research and community service (UT4) and the unabsorbed research and community services budget (UT6 and UT7);

d. Improve work equipment and laboratory equipment and provide teaching and research software. Besides providing laboratory equipment and research and teaching software, resource sharing is important. Any equipment and software must be shared with other departments. It will reduce waste equipment movement (MOT2), no necessary equipment available in the room/classroom (TRP4), and waste required materials/ equipment not available (INV3);

e. Integrated course schedule development. Course schedules and room usage should be prepared jointly between study programs. It will reduce waste course schedules that cause students to wait (WAIT1), unbalanced lecture daily schedules (OPR4), moving between classrooms (MOT1), inappropriate class capacity (INV2), and unused classrooms (DEF5).

5. Conclusions

The criticality level of waste (*CLoW*) framework developed in this article can be used by organizations, especially HEIs, to determine waste reduction priorities. This framework has been applied to a private university and can be applied in a public university because both have the same business process, namely, the three pillars of the HEI process: teaching, research, and community service, as well as supporting activities. The prioritization of waste that must be reduced becomes the starting point for the improvement plan. HEI stakeholders include students, graduate users, students' families, university leaders and employees, suppliers, secondary schools, other universities, industry, the state, government, taxpayers, and professional organizations [42,65]. In this article, we determined the priority of waste reduction, considering the input of four stakeholders, namely students, academics, non-academic staff, and HEI leaders. It is relevant because these four stakeholders can determine the existence of waste. The practical contribution of this study is that this framework can be used for waste prioritization in HEI as well as in school. The theoretical contribution of this study is to fill the research gap of waste reduction prioritization in all aspects of HEI activities, involving all HEI stakeholders involved in the business process (i.e., students, academics, non-academic staff, and HEI leaders). The limitation of this research is that it only determines the priority of waste reduction and provides suggestions for improvement. Considerably more work will need to be done to develop selection methods of improvement projects to reduce waste. Another possible future research avenue would be to use multi-criteria methods to determine *CLoW*.

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Appendix A

Dear Students, academic, and non-Academic Staff

Please help to fill out the questionnaire for our research. This questionnaire is solely used for academic purposes. All data collected will only be used for academic purposes.

For all your help and cooperation, we thank you.

Explanation and Instructions for Completing the Questionnaire:

1. Waste is any activity that uses resources but does not add value to the customer.
2. Waste in higher education describes all activities in the field of education/teaching, research, and community service as well as supporting activities that do not provide added value (non-value-added activity);
3. Give your opinion about the occurrence of waste where you work/college, by crossing (x) one of the answers below.

1: Never Occurs (NO)
2: Rarely Occurs (RO)
3: Often Occurs (OO)
4: Very Often Occurs (VOO)
Gender: M/F
Faculty:

Table A1. The questionnaire occurrence level of waste.

No.	Waste	Occurrence			
		NO	RO	OO	VOO
1	Excessive/repetitive information/announcements	1	2	3	4
2	Establishment of unnecessary academic and administrative units	1	2	3	4
3	Provision of unnecessary facilities	1	2	3	4
4	Unbalanced lecture daily schedule	1	2	3	4
5	Lecturers print out too many lecture materials, questions, journals, etc.	1	2	3	4
6	Too academic staff	1	2	3	4
7	Repetitive work/tasks	1	2	3	4
8	Courses that are too varied	1	2	3	4
9	Repeated document checks and approvals	1	2	3	4
10	Meetings with the same topic repeatedly	1	2	3	4
11	Repeated entry of the same data	1	2	3	4
12	Unnecessary or excessive report/task	1	2	3	4
13	The lecturer discusses the same topic repeatedly	1	2	3	4
14	Long bureaucracy	1	2	3	4
15	Course schedules that cause students to wait	1	2	3	4
16	Waiting for document approval	1	2	3	4
17	Waiting for the procurement of goods	1	2	3	4
18	The information system or internet is a breakdown				
19	Waiting to search for files, books, or documents	1	2	3	4
20	Awaiting repair of broken facilities	1	2	3	4
21	Long research proposal submission process	1	2	3	4
22	Moving between classrooms	1	2	3	4

Table A1. *Cont.*

No.	Waste	Occurrence			
		NO	RO	OO	VOO
23	Equipment movement	1	2	3	4
24	Equipment is stored away from where it is used	1	2	3	4
25	Movement of documents or materials	1	2	3	4
26	Bringing lecture materials, books, and teaching equipment to the classroom/laboratory.	1	2	3	4
27	Scatter campus location	1	2	3	4
28	No necessary equipment available in the room/classroom	1	2	3	4
29	Over inventory of material/stationery	1	2	3	4
30	Inappropriate class capacity	1	2	3	4
31	Required materials/ equipment not available	1	2	3	4
32	Lecture/research materials/equipment not available (journals, laboratory equipment, software)	1	2	3	4
33	Many similar documents	1	2	3	4
34	Purchasing materials before they are needed	1	2	3	4
35	Keeping documents for too long	1	2	3	4
36	Lost or missed information	1	2	3	4
37	Repeated work at the end of term, e.g., remedial, re-correction	1	2	3	4
38	Data entry error	1	2	3	4
39	Broken equipment or infrastructure	1	2	3	4
40	Unused classrooms	1	2	3	4
41	Incomplete documents	1	2	3	4
42	Error entering mark	1	2	3	4
43	Unused talents/skills	1	2	3	4
44	Knowledge or expertise that is not shared	1	2	3	4
45	Academic/non-academic staff assignments that are not under their expertise	1	2	3	4
46	Lack number of research and community service	1	2	3	4
47	Journal databases are rarely used	1	2	3	4
48	Unabsorbed research budget	1	2	3	4
49	Unabsorbed community services budget	1	2	3	4

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