SustainAct

How do I separate trash on the campus?

What would I change?

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TUM: Junge Akademie

Project Report **SustainAct**

Environmental concern and awareness of proper waste treatment is generally attributed to the academic environment. In our project SustainAct, we tried to find out whether TUM can actually be attributed a pioneering role in waste separation. To this end, we conducted an online survey among TUM students, staff and alumni to ascertain the current status of waste separation and to investigate potential for improvement. The results show that there is a strong awareness for waste separation, but that the possibilities for correct separation on site are not always given, which indicates potential for optimization. Recommendations for promising measures are given, emphasizing the importance of a TUM-wide approach.

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Preface by the Tutors

Veronika A. Bauer and Rodrigo de Rojas

Waste is one of the most crucial problems of our generation. For years, the amount of waste being produced has been steadily increasing. Waste gets thrown away thoughtlessly, pollutes landscapes, rivers, the sea. Even at the bottom of the Mariana Trench, the world's deepest oceanic trench, waste has been found. One important method in the fight against waste pollution is garbage separation. It not only supports waste avoidance but also enhances the retrieval of resources. Especially in times of increasing resource scarcity, recycling is key.

Waste separation is a crucial process that targets the efficient management of waste materials in any community. In Germany, waste separation is mandatory and has become part of the DNA

of many of us. Waste separation has gained significant attention in various sectors, including educational institutions.

Personell within the university structure play a critical role in the successful implementation of waste separation, including the waste management team, the cleaners and sanitation workers, and the faculty and students.

Many TUM students and employees have integrated waste separation into their daily university life even though the amount of waste that is correctly separated at TUM still admits of improvement. This issue has also been recognized by team SustainAct. In collaboration with the Green Office Weihenstephan, the team developed and conducted a survey, revealing many of the obstacles to successful waste separation whilst showing how waste management can be improved.

Despite an uneven start, the loss of many team members, and several setbacks, all three members of SustainAct committed to this important topic. With dedication, motivation, and curiosity, SustainAct asked about 170 members of TUM on how to improve waste management at TUM. The enthusiastic feedback is proof that SustainAct really hit a nerve. Now it is up to TUM to take advantage of this opportunity, build robust waste separation policies and guidelines and step up their waste management game. ■

Excellence and Sustainability: Implementation Remains a Challenge

With its breathtaking views of the Alps and vast green spaces, the Weihenstephan campus occupies the Weihenstephaner Berg. This expansive campus rarely sees large crowds as students are dispersed among various buildings. It is a perfect setting for discussions on sustainability at the Technical University of Munich (TUM). The Freising campus, known as Weihenstephan, is often cited as a shining example. Here, approximately 5,000 students immerse themselves in "Life Sciences," fields closely intertwined with nature.

A revealing scene unfolds at lunchtime, as hunger lures students out of lecture halls, offices, and the library towards the cafeteria. Discarded gum wrappers, coffee cups, and scribbled papers accumulate. But where can environmentally conscious students and staff dispose of their waste without resorting to general waste bins? As early as 2001, TUM implemented a comprehensive waste management system in Freising, placing significant emphasis on waste separation. More than 40 "Müllinseln" (recycling islands) with dedicated bins for different types of waste were strategically positioned across the campus. The aim was to provide waste separation facilities in offices as well. However, a stroll around the campus reveals that waste separation is not always straightforward. While some buildings offer proper waste separation options, many others lack clearly labeled bins or only provide general waste bins.

To address this issue, TUMJA launched a project, “SustainAct,” to assess the state of waste separation at various TUM locations. They conducted a quantitative survey among students and staff, which exposed weaknesses in the current waste management practices. Feedback from approximately 170 participants highlighted concerns. Some students questioned the availability and labeling of waste bins, expressing frustration with the difficulty of identifying the appropriate bin. Meanwhile, employees voiced their exasperation with waste disposal companies, lamenting the futility of waste separation efforts when cleaning services simply mix everything back together. "We have been complaining about this for years, drawing attention to the issue, but nothing changes,"

one employee emphasized. Despite these challenges, some resourceful individuals devised their own waste separation systems, overcoming the lack of clarity. However, there remains uncertainty about whether the cleaning staff will adhere to these efforts, prompting suggestions to involve them in awareness campaigns.

Recognizing the issue, the TUM Green Office Weihenstephan has taken action. Committed students are working towards implementing TUM's sustainability strategy at the Weihenstephan campus. Collaborating closely with the Waste Management and Environment department of TUM Campus Management, they have developed a waste separation strategy for kitchens and common areas in departments, led by Prof. Sara Leonhardt and the Chair of Plant-Insect Interactions. This strategy is set to be implemented soon. Furthermore, plans are underway to launch an awareness campaign featuring posters promoting proper waste separation.

The survey also revealed ideas for measures that could facilitate waste separation in daily life. Participants expressed a desire for more information on the fate of the waste they separate, suggesting that showcasing the recycling processes in the Munich area and Straubing could enhance motivation for proper waste disposal. An information campaign holds promise. Additionally, given the inconsistent availability of suitable waste bins, it is crucial to integrate sustainability criteria into waste management practices and ensure compliance from third-party cleaning companies.

The Weihenstephan campus stands as a symbol of excellence and sustainability, yet challenges in implementing effective waste separation persist. However, concerted efforts and initiatives are underway to address these issues and foster a greener future for the university community. ■

SustainAct – Waste Separation at TUM

Abstract
Our modern society is characterized by consumerism, often referred to as a leading cause of environmental pollution, which continues to stress ecosystems all around the world. Consequently, the importance of Mother Nature and the pressing need to preserve it for future generations is increasingly becoming the focus of today's society. Waste separation is hereby seen as one of the basic concepts to reduce disposal of waste into ecosystems.

Environmental concerns and awareness of the need for proper waste treatment are generally seen as notable attributes of academic environments. Universities all around the globe are depicted as showpieces for waste separation, as they are seen as entities already having implemented comprehensive environmental policies. In our project SustainAct, we tried to find out if a position on the frontier of waste separation is actually to be attributed to TUM. Thus, we surveyed the current status of waste separation and investigated potential areas for improvement.

For this purpose, we conducted an online survey among students, employees and alumni of TUM. We generated preference weights for different measures to improve waste separation, following the analytical hierarchy process (AHP) methodology. The analysis of relational data required compositional data analysis (CDA). The results show that there is strong principled commitment to waste separation among TUM employees and students, but possibilities to perform separation correctly on site are not always available, pointing to potential points of optimization. Advice on promising measures is given, stressing the importance of a TUM-wide approach.

1. Background

Germany was for a long time considered a perfect example of a "throwaway society," as were other leading industrial nations. Products were disposed of en masse after a single use, broken items were replaced with new ones instead of being repaired and reused. As a result, this led to enormous amounts of environmentally harmful packaging waste. In recent years, for example, up to 13.1 million tons of residual waste have been generated each year, which is equivalent to the weight of 1,300 Eiffel Towers and around 5 million tons of CO2eq. To absorb this amount of CO2, a forest area of 500,000 ha would be required, which is 2.5 times the area of Monaco (Umweltlifeguide-Nachhaltig Wohnen und Leben in München, 2023). Converted to individuals, private households recorded an average of 78 kilograms of packaging waste per capita in 2020 (Die Bundesregierung, 2023). However, this is not a problem limited to Germany, but a global challenge that needs to be addressed.

One possible approach to solving this problem is to move away from a “throwaway society” and toward a circular economy. The aim is to close material cycles by reusing all waste as raw materials and thus conserving natural resources. Hence, a circular economy represents effective climate and resource protection and, at the same time, offers an opportunity for sustainable economic development and new employment (Die Bundesregierung, 2023).

Germany has therefore embarked on such a path with developments towards a more sustainable use of natural resources. Thus, since June 1, 2012, the Closed Substance Cycle Waste Management Act (Kreislaufwirtschaftsgesetz) has provided the legal framework for waste management in Germany. The law’s purpose is to promote a circular economy in order to conserve natural resources and to reduce environmental pollution (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2023). In this context, Germany applies the so-called principle of waste hierarchy from waste avoidance to reuse, recycling and other recovery, with disposal as ultima ratio (Die Bundesregierung, 2023).

Recycling in particular is an important element of a circular economy. It involves recovering raw materials from waste, keeping used materials in a continuous life cycle by processing them into new products, ultimately reducing the amount of waste. Almost all waste is suitable for recycling, especially glass, paper and cardboard, plastics, but also iron and metals. Used glass can be remelted and reprocessed as often as desired. Moreover, the use of recycled paper conserves forests and contributes to climate protection. It also performs significantly better in terms of wastewater pollution, and of water and energy consumption, than paper products made from the primary fibers of pulp and groundwood.

Proper separation of waste is essential for recycling, especially when it comes to plastics and packaging waste. In addition, valuable raw materials such as aluminum, iron, nickel and lead can be recovered, e.g. from spent batteries in special processes (Die Bundesregierung, 2023).

However, despite a recycling rate of 79% (Die Bundesregierung, 2023), achieved even though 40% of compostable organic waste is disposed of in residual waste (Umweltlifeguide-Nachhaltig Wohnen und Leben in München, 2023), too much packaging waste is still produced in Germany. Legal requirements have been introduced to avoid single-use plastic and to strengthen reusable offerings. For example, numerous single-use plastic products have been banned throughout the EU since July 2021, and lightweight plastic bags since January 2022. The majority of plastic beverage bottles are now recyclable. In order to recover more recyclable materials, higher recycling rates were introduced for all types of packaging in January 2022. For this reason, at least 90% of packaging made of ferrous metals, aluminum, glass, paper, cardboard and cartons must be recycled, while the minimum rate for beverage cartons is 80% and for plastics 63%. In addition, the proportion of plastics in bio-waste that is composted, fermented or mixed with other materials must be reduced to a maximum of 0.5% (Die Bundesregierung, 2023).

In order to improve waste recycling, the waste separation requirement is to be strengthened in the future. Accordingly, public waste management authorities are obliged to collect biowaste from private households separately in order to subject it to a high level of material recycling such as composting (§ 20 Absatz 2 Satz 1 Nummer 1 KrWG). This serves to improve regular waste recovery in the sense of the waste hierarchy mentioned above (§ 9 Absatz 1 i. V. m. § 7 Absatz 2 bis 4 und § 8 Absatz 1 KrWG) (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, 2021).

Correct waste separation is therefore an essential prerequisite for proper recycling and thus the foundation of sustainable waste management. Packaging must be sorted correctly according to material type so it can subsequently be processed in an environmentally friendly manner. Residual waste is incinerated unsorted, while bio-waste is used to generate energy such as electricity and heat (Umweltlifeguide-Nachhaltig Wohnen und Leben in München, 2023). As already mentioned, waste separation is legally prescribed in the Closed Substance Cycle Waste Management Act §14 (1) and, as a global challenge, concerns every individual in our society. Its non-observance is associated with the loss of valuable resources, dramatic environmental consequences and enormous economic costs (Mülltrennung-wirkt, 2023).

As a university institution with wide-reaching influence, TUM has an obligation to take up and advance solutions to social problems like waste separation. It is striking that TUM has not yet implemented a uniform strategy on waste management. The availability of trash bins that allow for waste separation seems to vary widely across campuses. While some offices are equipped with trash bins for paper and mixed trash, there are several offices with only mixed ones. Similar observations can be made in public spaces. Buildings on campus are mostly equipped with trash bins for mixed waste, while multi-purpose trash bins are rare. A lack of reusable bins can also be observed at the WZW campus in Freising. In 2019, a new waste management strategy was implemented at WZW. New trash bins are to enable waste separation. For this purpose, so-called "trash islands," i.e. places for central trash collection, were set up throughout the campus. However, there do not yet seem to be any facilities for waste separation in the public areas and offices. Thus, waste separation is mainly possible at the "waste islands."

The objective of this study is to investigate the current status quo of waste separation at TUM and to offer some suggestions for improvement strategies and indicate their benefits.

2. Methodology

2.1. Analytic hierarchy process (AHP) and compositional data analysis (CDA)

With several campaigns planned to improve waste separation at TUM, the goal of this study was to capture the status quo of waste separation at TUM. A further target was the identification of promising measures which could help to improve waste separation. The results should help with the development of promising measures capable of enhancing waste separation, especially by uncovering

the average importance of each measure, as well as the heterogeneity in preference.

The following five measures for improved waste separation were compared:

1. More multi-purpose bins (Bins)
2. More bins of the current type, meaning less time to the next bin (Time)
3. Content information on each bin, for example stickers listing items belonging in the respective bins (Information)
4. Campaign for higher awareness of the importance of waste separation (Awareness)
5. Improved waste treatment by disposal companies (Collection).

A comparison of different measures would facilitate a labeled discrete choice scenario. While the different measures could be described and compared based on attributes, there is no realistic scenario that incorporates a price attribute. This assumption is grounded on the idea that waste separation lies within the responsibility of TUM as an organization. Neither students nor employees would be willing to pay for measures on waste separation; neither would they be willing to accept compensation for sub-optimal separation possibilities. Proper disposal and treatment of waste should have been a long-established given. It is, as a result, not possible to construct a utility function, ruling our discrete choice analysis.

The analytic hierarchy process (AHP) invented by Saaty (1977, 1980) is a weighting method that can be applied in case a utility function cannot be formulated. The first step of AHP is problem formulation. Next, respondents prioritize alternatives based on individual comparisons, stating the importance of an attribute in relation to another attribute. A comparison of each pair of attributes leads, in the five-attribute case, to ten comparisons. Priorities are calculated once data is collected. It is possible to generate individual and aggregated priorities (Ishizaka, 2013).

A consistency check ensures that the transitivity and reciprocity rules are respected (Ishizaka, 2013). Saaty (1977) developed a consistency index, which is based on the eigenvalue

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

with λ_{max} as the maximum eigenvalue. A comparison of the consistency index with the average consistency ratio of 500 randomly generated matrices, leads to the consistency ratio of each matrix.

$$CR = \frac{CI}{RI}$$

The random index with five attributes and 1000 simulations was set to a value of 1.115356. Figure 1 shows the consistency ratio of individual matrices using linear scaling. The weighting matrices show high inconsistency, which would lead to inconsistent aggregated priorities. Harker's method can be applied to reduce the inconsistency in individual preference matrices (Saaty, 2003). The most inconsistent pairwise comparison of each matrix is replaced by a consistent weight based on the eigenvalue. This process can be repeated several times, with each iteration leading to a loss of information. The number of iterations should hence be kept as low as possible.

Transforming the preference statements from a linear to a logarithmic scale increases consistency (see Figures 1 and 2).

The first iteration leads to an increase in consistency, while further iterations only have marginal effects. The logarithmic transformation in combination with one iteration of Harker's method was applied to deduct priority weights.

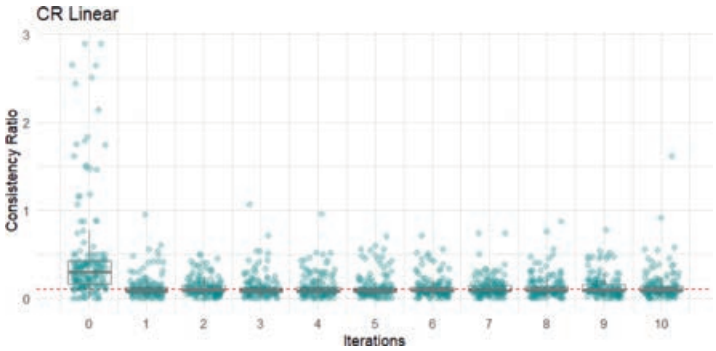

Figure 1: Consistency of compositional data after one iteration following a linear weighting by Saaty (1977)

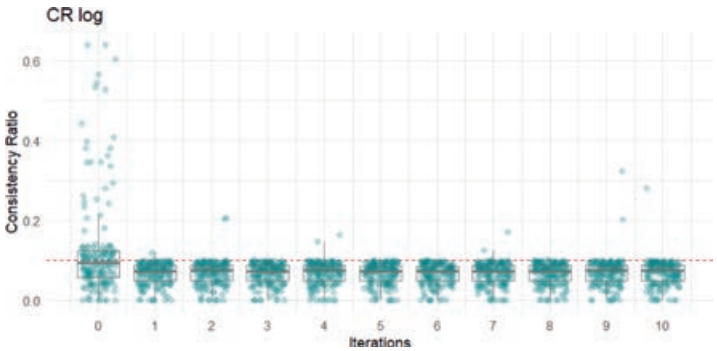

Figure 2 Consistency of compositional data after one iteration following a linear weighting by (Ishizaka et al., 2006)

The generated priority weights resemble compositional data. Handling compositional data requires special care. The Simpson's Paradox explains a prominent issue when it comes to aggregation of compositional data. In the following example, the share of male and female students arriving late to class is recorded in two classrooms (see Figure 3). The aggregated arithmetic means indicate that more men than women were on time if aggregated over both classrooms, even though the share of female students arriving on time is larger for both classrooms (Pawlowsky-Glahn, 2013). Geometric means are applied to avoid problems with arithmetic space.

	Classroom 1		Classroom 2		Total	
	On time	Late	On time	Late	On time	Late
Men	53	9	12	6	65	15
	0.855	0.145	0.667	0.333	**0.813**	0.188
Women	20	2	50	18	70	20
	0.909	0.091	**0.735**	0.265	0.778	0.222

Figure 3: Example of Simpson's Paradox from Pawlowsky-Glahn et al. (2013)

2.2 Analysis of compositional data

Statistical analysis of compositional data does not follow classical statistical properties. Compositional data is part of the so called simplex, or compositional space. Compositionally equivalent results can be achieved with different levels of physical amounts, as represented by points P and P‘ in Figure 4. Point P could represent a fixed share of renewable energies in the national energy production mix. Point P‘ is compositionally equivalent, which could be achieved by an increase in renewable energy production, just as with a reduction in non-renewable energy production.

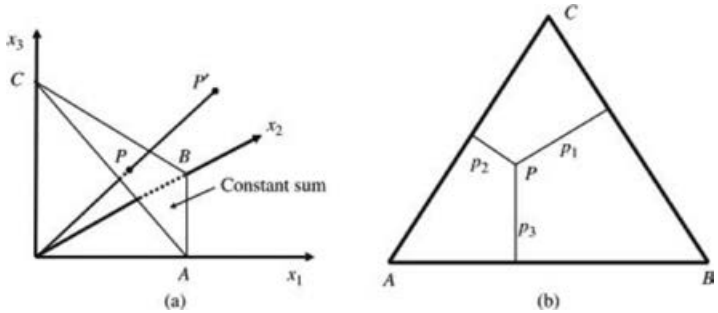

Figure 4: Simplex imbedded in $\mathbb{R}$ 3 (a) and Ternaty Diagram from Palowski (2015)

Special care has hence to be taken if composition data is to be analyzed with conventional statistical techniques. All conventional calculation methods can be applied once the compositional data has been transformed using the Isometric Logratio Transformation (ILR). All common mathematical operations are viable once the data is transformed, but interpretation is not straightforward due to the factorial character of the transformed data (Palowski, 2015).

2.2. Aggregation of variables for analysis

Several control variables were aggregated for analysis. The campuses of Heilbronn, Ottobrunn and Singapore were aggregated to one campus due to a low number of observations. Participants were further grouped into three income groups, with 25 percent of respondents having a monthly income below 1.000€, 50 percent of observations with a medium income between 1000€ to 2.200€ and 25 percent of respondents with a “high income” above the q75 value of 2.200€. Two age groups consisting of individuals below and above the median age of 28 years are distinguished.

The attitude of participants towards nature is controlled by following the standardized approach “NR-6”, which is a standardized approach in psychology to measure environmental relatedness. This approach is often followed as a control due to it’s small item battery of six questions only (Nisbet, 2013).

3. Outcome and Discussion

3.1. Demographic Data

Our survey encompasses data from a total of 175 respondents. The responses of four participants had to be removed due to erroneous answers, resulting in a final sample size of 171 participants. Among these respondents, there were 79 students and 95 employees of TUM. Interestingly, 6 of the employees were also students at TUM. Additionally, 3 TUM alumni took part in the survey.

The participants represented various TUM campuses, including TUM city, Garching Forschungszentrum, Freising (WZW), Straubing, Heilbronn, Ottobrunn, and Singapore (Table 1). They also belonged to different Schools and Faculties within TUM (Table 2).

In terms of gender distribution, approximately 60% of the participants identified as female, while 40% identified as male (Table 3). Given the significant number of employee participants, the age range varied from 18 to 62 years, with a median age of 28 years.

Campus	Number of participants
Munich City	56
Garching Forschungszentrum	50
Freising (WZW)	31
Straubing	25
Heilbronn	2
Ottobrunn	1
Singapore	2

Table 1: Number of participants from each TUM campus

School or Faculty	Number of participants
TUM School of Computer, Information and Technology	25
TUM School of Engineering and Design	33
TUM School of Natural Sciences	32
TUM School of Life Sciences	31
TUM School of Management	19
TUM School of Social Sciences and Technology	8
Faculty of Medicine	6
Faculty of Sport and Health Sciences	3
None	14

Table 2: Number of participants from each TUM school or faculty

Gender	Number of participants
Male	64
Female	103
divers	0
NR	4

Table 3: Number of participants sorted by identified gender

Another demographic factor analyzed was the monthly income of the participants, who had an average income of 2,150€ and a median of 1,700€. Respondents' nature relatedness, with a mean score of 3.8, above average, indicates slight selection bias towards high environmental awareness.

3.2. Status Quo of Waste Separation at TUM Campuses

The results show that the majority of participants (over 90%) consider the effect of waste separation on the environment to be beneficial (Figure 5). Furthermore, a high level of agreement with the principle of waste separation in general is found among the participants (Figure 6). The results further reveal that a majority of participants believe that individual waste separation is more efficient than waste separation at the trash yard (Figure 7).

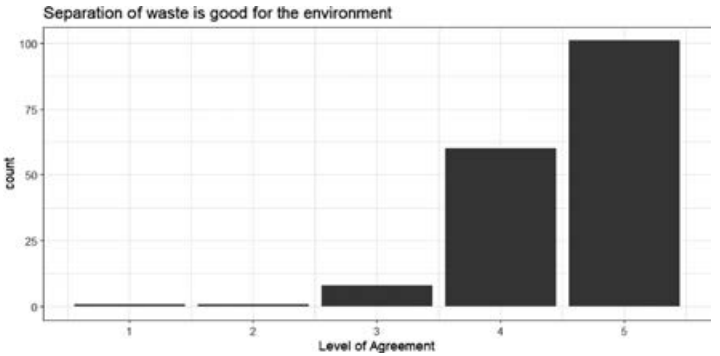

Figure 5: Level of agreement with statement that waste separation is good for the environment in absolute numbers

Knowledge about a TUM-wide color scheme for waste bins is heterogeneous, indicating a lack of uniformity in participants' perceptions (Figure 8).

Appropriate use of waste bins depends on the type of trash. Paper is separated into a bin for paper waste, while glass is often thrown

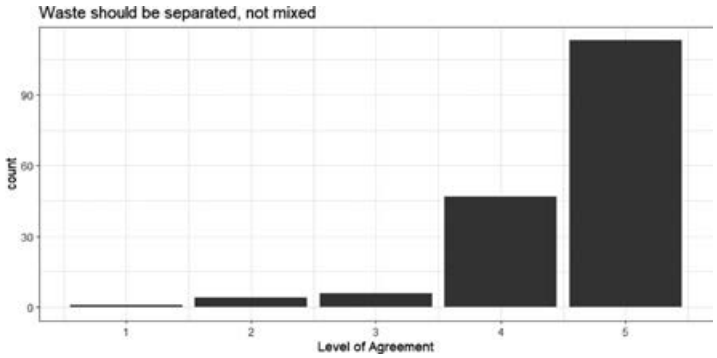

Figure 6: Level of agreement with statement that waste should be separated rather than mixed in absolute numbers

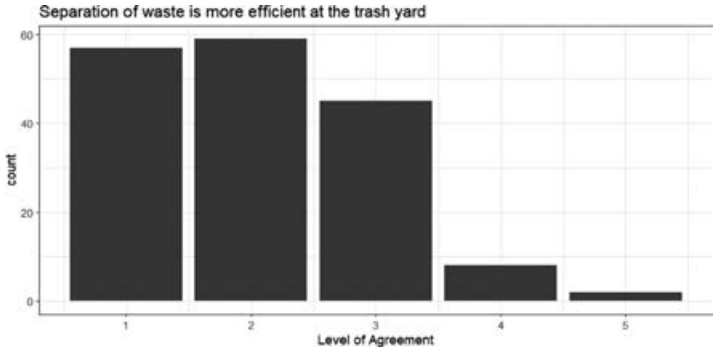

Figure 7: Agreement of participants regarding more efficient separation of trash at trash yard in absolute numbers

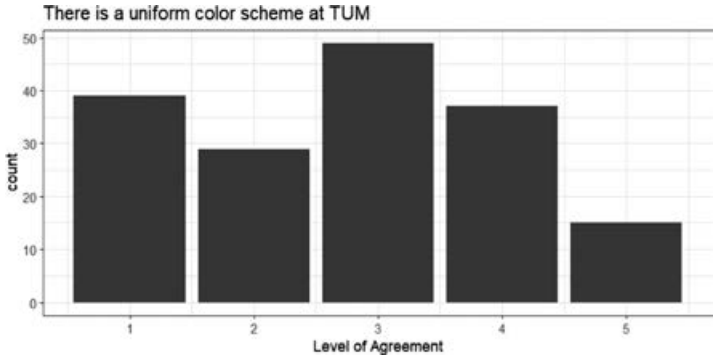

Figure 8: Agreement of participants regarding uniformity of color scheme of trash bins at TUM in absolute numbers

into mixed-trash bins. Our results indicate that plastic-metal composites are not separated similarly, with only a small share of respondents indicating that plastic-metal bins (yellow bag) are used. More than 50% of the participants disagree that bio-waste bins are used correctly (see Figure 9).

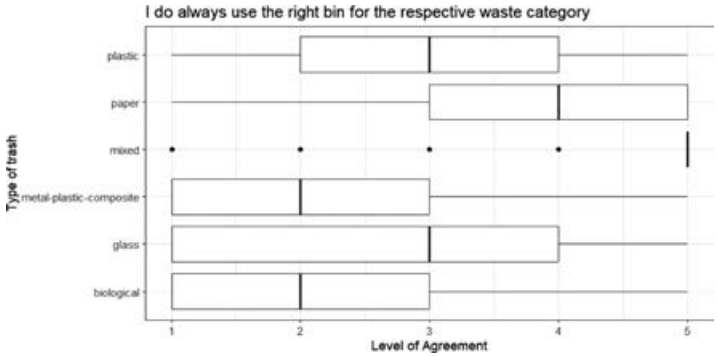

Figure 9: Correct use of waste bins with respect to different waste categories from strongly disagree to strongly agree

About 60 percent of the respondents state that they are willing to invest extra time to use a multi-purpose instead of a mixed bin. While this is a promising result, questions on actual use of waste bins with respect to the time needed to find a bin indicate a gap between willingness to separate and actual waste separation practice (see Figure 10). It takes too long to find a waste bin for biological or plastic-metal composition material. Answers regarding pa-

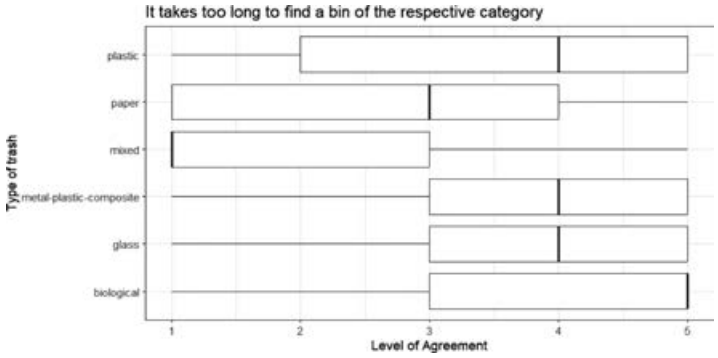

Figure 10: Low availability of trash bins with respect to different trash categories from strongly disagree to strongly agree

per bins are more heterogeneous, indicating that even separation of paper is not always possible. Only mixed-trash bins are largely reached in time.

More than 80% of the participants agreed that more efforts could be made to reduce waste (Figure 11). This indicates that waste management is not sufficient.

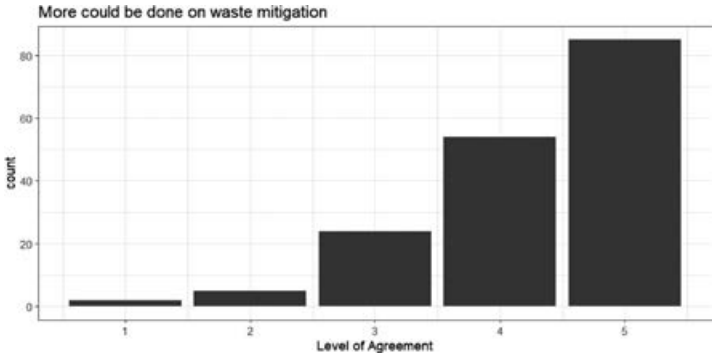

Figure 11: Agreement of participants regarding necessity of more efforts on waste mitigation in absolute numbers

3.3. Descriptive Results of the Compositional Data

Potential measures to improve waste separation were weighted by each respondent. The geometric mean of the preferences shows that the installation of more multi-purpose bins and improved waste collection and management are the most preferred measures (see Figure 12). Awareness campaigns and information on trash bins are less favored. With less time to the next bin, the least favored, there is an indication that waste separation is not hampered by the quantity of available trash bins. The geometric means reveal a large heterogeneity across respondents. Improved waste collection and management shows the largest upwards directed standard deviation, further indicating that improved trust in the waste change after disposal by the individual could be a promising measure.

Targeted measures can only be applied if the large heterogeneity in the preference weights is dismantled. The data on geometric means by campus seem to add little explanation (Figure 13).

Respondents from the campuses Munich city and Straubing weigh more multi-purpose bins approximately 5 percent more important

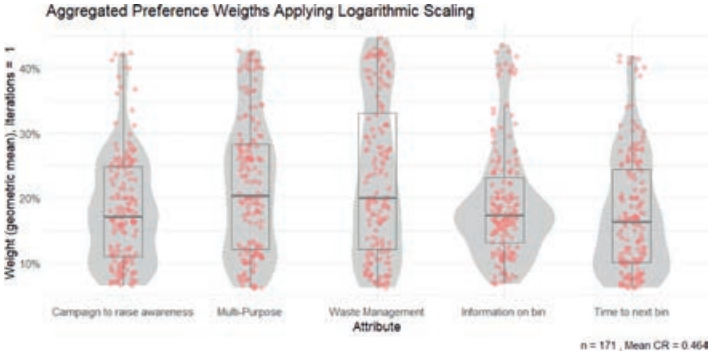

Figure 12: Aggregated geometric mean of preference weights of different measures to improve waste separation

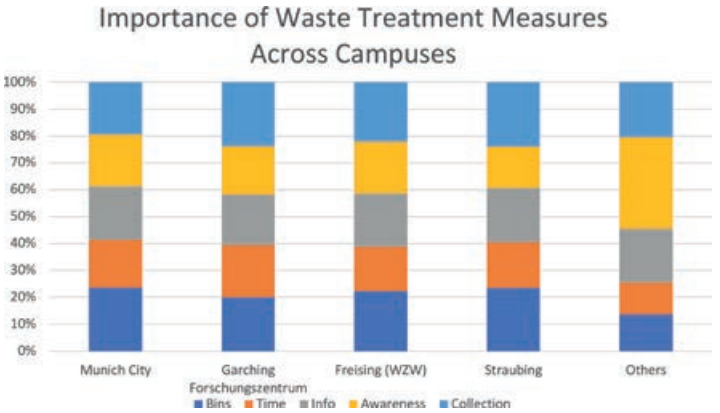

Figure 13: Compositional Data Analysis - Comparison of waste treatment measures across campuses of TUM

than at other campuses. An awareness campaign seems to be less promising in Straubing, while Straubing and Garching place the highest weight on improved garbage collection and management. The category of other campuses seems to diverge significantly, with an awareness campaign as the most promising measure.

Geometric means were also calculated for each school of faculty of TUM, again with evident differences in preference weights (Figure 14).

Students and employees from the faculties of Medicine and Sport and Health Sciences put great importance on provision of more

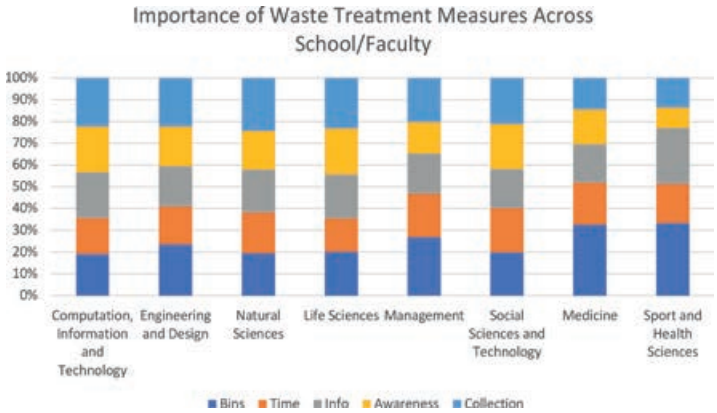

Figure 14: Compositional Data Analysis - Comparison of waste treatment measures across schools and faculties of TUM

bins (>30%) and are closely followed by the School of Management. There seems to be no difference in the preference for a measure introducing more bins. A comparably large share of participants from the Faculty of Sport and Health Sciences would like to have more waste separation information on the bins. An information campaign seems to be less promising at the School of Management and the Faculty of Sport and Health Medicine. There seem to be further differences of importance regarding improved waste collection, with members of the Faculty of Medicine and Sport and Health Sciences considering improvements in this direction less important.

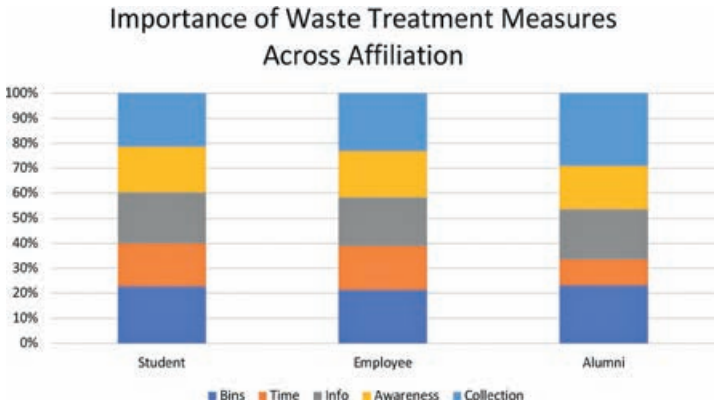

Figure 15: Compositional Data Analysis - Comparison of waste treatment measures across affiliation to TUM

Differences between employees and students are small, which seems logical considering that both groups should mostly use the same facilities.

Alumni of TUM diverge from active members, as they seem to put more weight on improvements on the waste chain after trash disposal and less weight on an increase in the number of trash bins, indicating that time constraints are less important for this group (Figure 15).

There is almost no difference in the importance of measures for improved waste separation across gender (Figure 16).

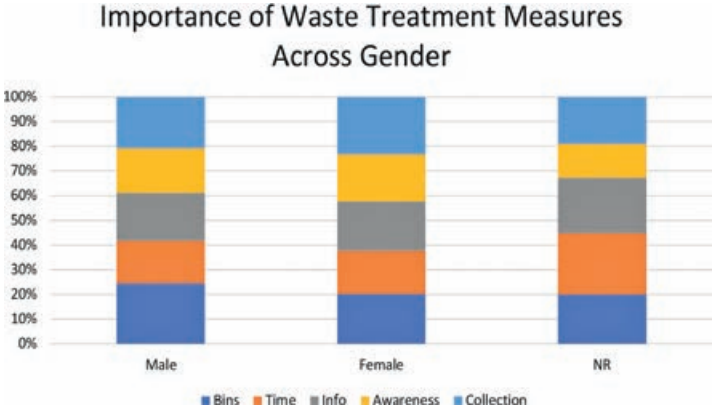

Figure 16: Compositional Data Analysis - Comparison of waste treatment measures across gender

Males seem to put slightly more weight on improvements of the quality of currently available bins. This is largely compensated by the measure of improved garbage collection after disposal, which females find to be more promising. The small group of non-binary participants prefers installation of more bins if compared to males and females, while this group seems more reluctant about an awareness campaign.

Differences between international and German students seem to be minor, with a small tendency that international students see

more bins of the current type to be more important compared to Germans. International students do meanwhile put less weight on an information campaign (see Figure 17).

Figure 17: Compositional Data Analysis - Comparison of waste treatment measures across country of origin

Differentiation by income reveals that members of TUM with a medium income seem to differ from the low and high income groups, which are very similar. Medium income members of TUM seem to put more weight on increased number of trash bins of the current type, and hence less time to the next bin, while an awareness campaign and information on the content of bins are less attractive for them (see Figure 18).

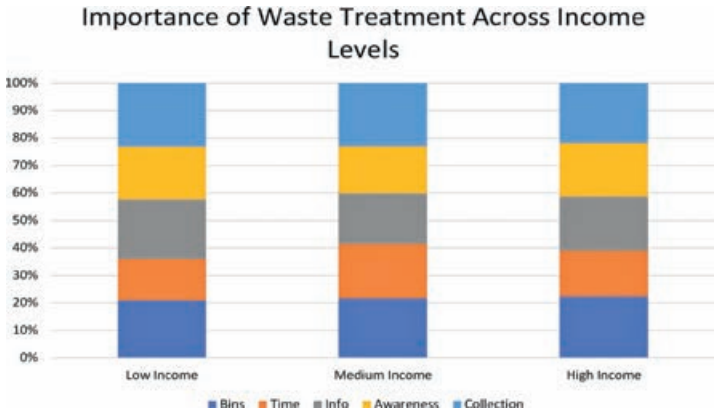

Figure 18: Compositional Data Analysis - Comparison of waste treatment measures across income levels

Comparing the importance of the mentioned measures between age groups, no individual tendencies could be identified (see Figure 19).

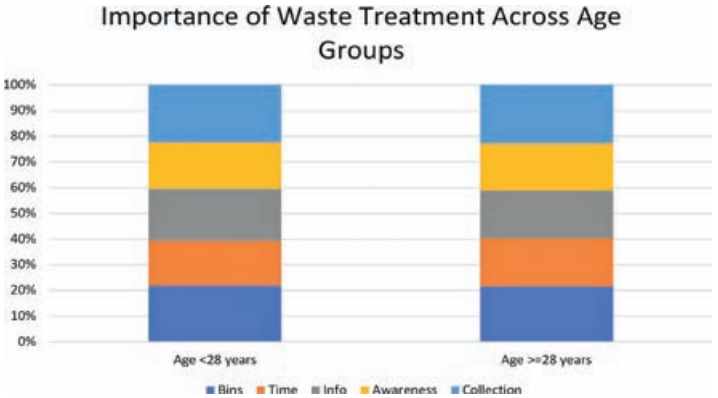

Figure 19: Compositional Data Analysis - Comparison of waste treatment measures across age groups

3.4. Measures for better waste separation and causality

An ordinary OLS regression on the ILS transformed data hints at a few causal relationships. Results with a p-value below 10 percent are discussed here, arguing that the sample size of 154 observations is quite low, most likely causing the remaining uncertainty. The coefficients and their p-values are reported in table 4.

The first regression unravels and differences in preference for the two measures More Multi-Purpose Bins (A) and More Bins of the Current Type (B). There is a weak but marginally significant causality between the ratio and the variables age and income, indicating that both older and respondents of higher income favor more bins of the current type over more multi-purpose bins. This observation holds for international students and the campus of Garching, as well. There is also a difference between genders, with male respondents putting more weight on a measure that increases the number of multi-purpose bins, instead of just increasing the number of trash bins currently in place.

Dependent Variable	A/B		AB/C		ABC/D		ABCD/E	
	ß	p-value	ß	p-value	ß	p-value	ß	p-value
Intercept	-0.24093	0.41	-0.27626	0.42	-0.48097	0.18	-0.45286	0.30
Age	0.00836 .	0.10	-0.00291	0.62	0.00558	0.36	0.01238	0.10
Income	0.00004 .	0.05	0.00000	0.84	0.00001	0.69	0.00000	0.93
Male	-0.17084 .	0.06	-0.14869	0.16	-0.10218	0.35	0.00080	1.00
Time of Affiliation	-0.00333	0.67	0.00857	0.36	-0.00940	0.33	-0.00846	0.47
NR-6 (Nature Relatedness)	-0.05878	0.35	0.16602 *	0.03	0.21029 **	0.01	0.03611	0.70
Working Days	0.00769	0.80	0.02477	0.48	-0.04224	0.25	-0.01625	0.72
Mitarbeiter	-0.12520	0.25	-0.06322	0.62	-0.09619	0.47	-0.03211	0.84
Alumni	-0.27676	0.41	0.18924	0.48	-0.14688	0.72	0.74476	0.14
International	0.29714 **	0.01	-0.16359	0.19	-0.27182*	0.04	0.10707	0.50
Garching	0.22638 .	0.08	-0.19657	0.20	-0.05964	0.70	0.16590	0.39
Freising	0.04724	0.81	-0.19132	0.41	-0.21034	0.38	-0.05072	0.86
Straubing	0.04800	0.74	-0.21099	0.22	-0.35979 *	0.04	0.24568	0.25
Other Campus	0.16653	0.55	-0.24595	0.45	0.40023	0.24	0.06689	0.87
Engineering	-0.07638	0.56	-0.3305 *	0.03	-0.24020	0.14	0.08119	0.68
Natural Sciences	-0.04815	0.73	-0.11350	0.49	-0.14363	0.40	0.09687	0.64
Life Sciences	-0.17226	0.39	0.05092	0.83	0.17911	0.46	0.17340	0.56
Management	-0.10361	0.51	-0.35219 .	0.06	-0.29578	0.12	-0.10684	0.65
Social Sciences	0.23487	0.27	-0.32762	0.19	-0.16050	0.54	0.08361	0.79
Medicine	-0.26613	0.26	-0.43604	0.12	-0.33556	0.25	-0.03671	0.92
Sport	-0.40813	0.28	-0.50314	0.26	-0.75981	0.10	-0.70237	0.21

Table 4: Regression on ILR transformed preference weights

Regression on Isomeric Log-Ratio transformed waste separation measures
A = More Multi-Purpose Bins, B=More Bins of current type, C=Content Info on Bins,
D=Awareness Campaign, E=Improved waste treatment after disposal n=154

The comparison of AB with C can be interpreted as the relative importance put on an improvement in the quality of the trash bins (more bins or better bins) compared to a measure where information is given on how to use existing bins. Members of the School of Engineering and Design and the TUM School of Management weight improved quality of trash bins as significantly more important than more information on the current bins than members of the TUM School of Computation, Information and Technology. The same trend holds for members of the TUM School of Medicine, although being marginally insignificant at the 10 percent confidence level. Another finding is that respondents with a high nature relatedness score favor information on bins over bin quality. This may indicate that people of high environmental awareness suffer lower disutility from searching for waste bins and are hence happier with the current availability and quality of trash bins, but are more concerned about correct waste separation.

The third regression uncovers tendencies in a comparison of bin-related measures (A, B and C) and an awareness campaign. The higher the environmental awareness, the more weight is put on an information campaign as compared to bin-related measures. This, again, could hint at lower levels of concern about the current waste separation system among environmentally sensitive TUM members. Another explanation could be low trust of environmentally oriented members in the waste separation behavior of their peers. International students meanwhile attribute significantly lower importance to an awareness campaign as compared to German members. The campus of Straubing differs from other campuses. Bin-related measures are seen as significantly more important than an awareness campaign. Although marginally insignificant at the 10 percent level, there is a clear tendency that members of the School of Engineering and Design, TUM School of Management and faculty of Sport and Health Sciences put less weight on an information campaign. This finding is especially interesting for the Schools of Engineering and Management, as both weighted bin-related measures were more important than information provided on bins. This could be a clear indication that members of both schools experience worse waste separation possibilities as compared to other TUM members. Another reasoning behind this tendency could be a stronger sense of relevance for members of both schools towards educational measures.

The comparison of on-campus measures (A, B, C and D) with improved waste collection (E) could not reveal any significant correlations. There is nevertheless the barely insignificant trend that older people and alumni weight improved garbage collection as more important than younger or active TUM members. This could be explained by their intermittent presence at TUM, and hence a lower level of inconvenience from poor waste separation possibilities.

3.5. Additional qualitative results in support of quantitative findings

The results reveal a high awareness among TUM members regarding their willingness to separate waste and awareness of waste separation as an environmental problem. Waste separation is largely seen as a practice with benefits for the environment, and hence understood as a responsibility on the personal level. This is supported by the finding that it is largely accepted to spend additional time searching for an appropriate waste bin, instead of just using a mixed trash bin.

Waste separation is, however, not always possible for all waste categories. In particular, biological wastes and plastic-metal composites are not disposed of properly. This lack of waste separation is mostly to be attributed to a lack of multi-purpose bins. Only mixed trash bins are readily available among most facilities of TUM. This finding goes hand in hand with a lack of knowledge of any trash bin related color scheme at TUM.

Qualitative feedback on issues regarding waste separation provide additional insights to the quantitative information described above. Concerns regarding the inconsistency in placement of trash bins was raised. To elaborate this further, it was reported that there are multi-purpose bins only in the common areas of many buildings, while no waste separation opportunity persists in office spaces. In most cases, there seems to be only a paper bin and a mixed-waste bin provided in offices. Some employees came up with creative solutions to ensure proper waste separation in these cases, with some of the employees even setting up their own waste separation system. The reported lack in multi-purpose bins goes hand in hand with a lack of trust regarding the waste collection after disposal by the personnel. There is general concern that trash is re-mixed, even if separated by the TUM members. Further criticism concerns special waste categories. Specific types of waste, such as hazardous wastes, electronic waste, wood waste and bulky waste, do not have any uniform disposal system across campuses of TUM.

There is a general consensus among TUM members regarding the need for more efforts to reduce waste. In an effort to reduce waste on campus, various suggestions were gathered via an open question. Suggestions include the implementation of additional organic waste bins and the introduction of multi-purpose and special use bins in central locations and offices. It was also suggested that packaging waste from food establishments could be reduced, e.g. by promoting the use of reusable containers or other packaging options. Reusable coffee containers are mentioned here, most likely since they are common in some but not all campuses of TUM. Excessive packaging is also reported for cafeterias. A transition to digital processes in the working space could further reduce waste, e.g. by digitizing printed forms to reduce paper waste. A high amount of avoidable paper waste seems to accumulate in libraries, where more digital solutions might be adopted. Bathrooms were named as a further source of paper waste, which could easily be reduced if hand dryers were to be installed.

3.5. Limitations

The survey conducted demanded proper answers from respondents in order to get consistent data, especially regarding the AHP ranking task. Consistent decisions require a relatively high cognitive performance by the participants. Information on the current consistency ratio or a thorough introduction into the methodology are hence often applied in research. It was expected that the maximum time spent on a survey on waste separation should not exceed five minutes. Therefore, a short survey was considered key for this study. The introduction to the AHP task was therefore kept as short as possible. This could explain why a linear scaling of the preference weights led to relatively high inconsistency.

Sample size puts a further limitation to our study. Some smaller campuses had to be aggregated. More differences between campuses may exist and could be elicited with a larger sample size.

4. Summary and Future Goals

Our survey highlighted the discrepancy between acceptance of waste separation behavior and actual behavior across various TUM campuses. We find that TUM members are willing to separate waste, but are not able to do so to a large extent. This is most likely due to the lack of multi-purpose trash bins. Unfortunately, only mixed bins, and for a large part also paper bins, are available in everyday campus life. TUM members are furthermore not aware of TUM-wide waste bin color schemes.

While some differences between campuses exist, especially regarding the acceptance of different waste improvement measures, there seems to be a general lack of multi-purpose waste bins across all campuses. The so called “Wertstoffinseln” are not working and should be reconsidered if increased waste separation at TUM was their main motivation.

Better collection of separated waste turned out to be the most requested measure, indicating a lack of trust in the current waste management system. We also observe that information and awareness campaigns are of lower importance in general, but also on the level of campuses (Straubing) or Schools (Engineering and Management).

A high acceptance of the practice of waste separation among TUM members was revealed. Some members are even separating waste if the respective bins are not present, or if there is a suspicion that waste is mixed during collection. We argue that waste separation is not an information or cultural problem, but an issue of management. Information campaigns would likely be of low effect, especially as long as the number of multi-purpose bins does not increase. Be it the working space, hallways or open spaces, the next convenient bin is the one most likely to be used. We further argue that the second most important measure, after the provision of multi-purpose instead of mixed bins, would be an improvement in waste collection. Waste separation has to be a standard for all sub-contracting firms. Communicating how waste is disposed of in a separated form would further help to build trust between TUM members and subcontractors.

Mere information campaigns on how to separate waste, or on the importance of waste separation, do not hold much promise; low acceptance of waste separation is a problem from the past. The encouraging message is that this is not a people’s problem, but a problem of management and infrastructure. ■

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Self-reflection

Team ‘Role Model’ initially started out with 12 passionate students from very different disciplines – sustainable resource management, medicine, health science, agriculture, biochemistry, engineering and education. After a few discussions at the first weekend seminar at the botanical gardens, we soon realized that our common interests lay in sustainability. Sustainability is not an easy theme to start with. Each team member had their own interpretation of the word and this led to inconclusive team meetings and dissatisfied team members. Over the course of a few months, our team numbers halved as several members of the team had to pull out due to various circumstances. We then narrowed down the topic to focus on the different interpretations of the word that people might have and team ‘SustainAct’ emerged. Our topic was still too vague, however, and eventually our team was dissolved in August 2022 due to conflicts of interest.

In November 2022, team SustainAct reemerged with three members. Our new topic materialized out of the previous discussions of our former team. Waste separation was always a topic of interest for our group due to its high relevance to everyday life and we decided to pursue it further and to investigate within the confines of TUM campuses.

Although we were behind schedule, we re-motivated ourselves and began to design a survey on waste separation behavior at TUM. Fortunately, the response to the survey was very positive, giving us a relatively large data set to analyze. We were able to derive some impressive results from our data, so in the end we were quite pleased with the final outcome.

Despite working productively and keeping to our strict schedule, our biggest challenge was running out of time. Looking back, it was a very stressful time, as the entire workload had to be handled by only three people. Fortunately, we were able to successfully complete the project on time and with a remarkably good team atmosphere that was driven by our enthusiasm for the subject.

All in all, we can conclude that we learned a lot from our time at TUMJA, both for our professional and personal development. When we started the project, we had no idea what an incredible journey lay ahead of us. Despite the eventful course of the project with its numerous obstacles, we managed to complete it successfully.

At this point, we would like to thank our tutors Veronika and Rodrigo, who have steadfastly accompanied us throughout the last 20 months. We would like especially to emphasize their constant availability and constructive support. They did not just support us with our topic, but they also helped us hold the team together through to the end.

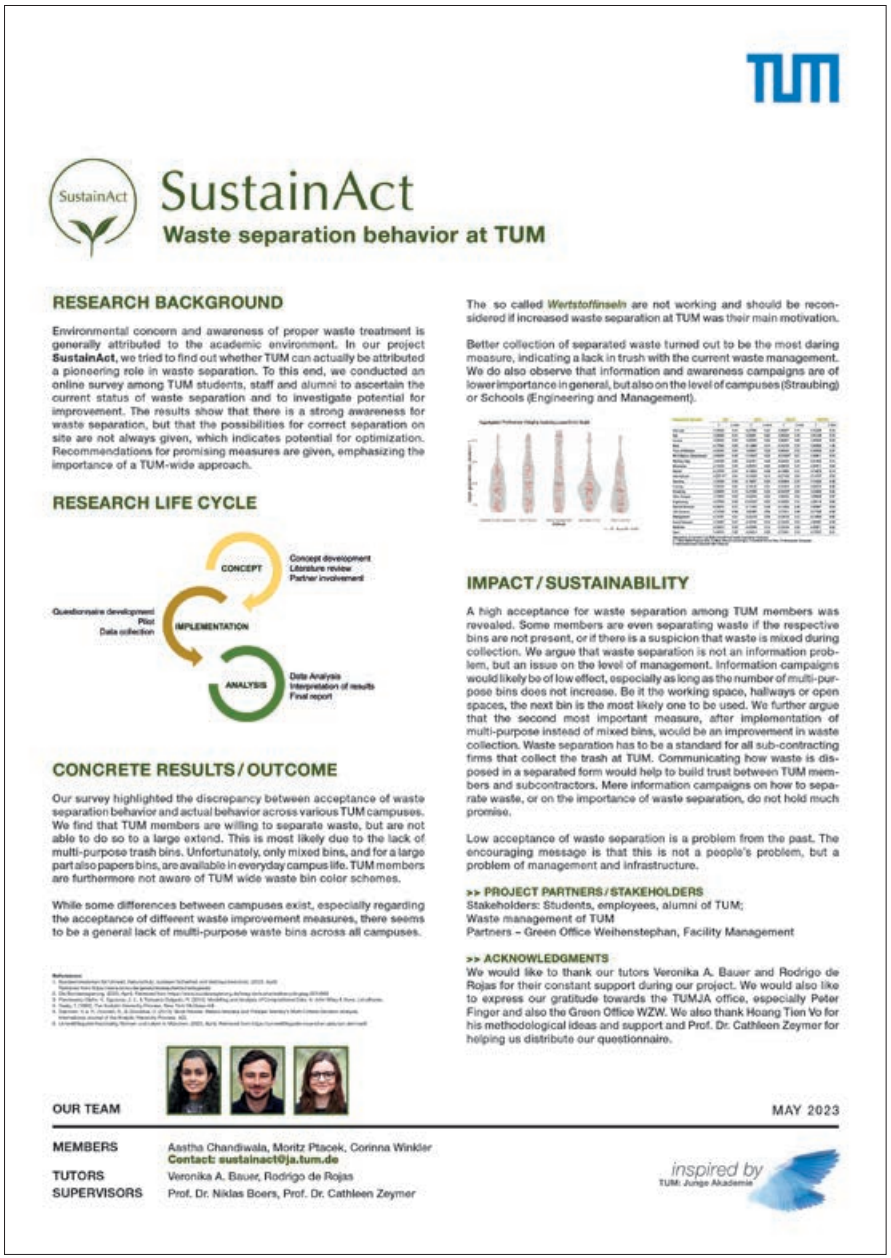
We would like to thank our former supervisor, Prof. Dr. Cathleen Zeymer, for her enthusiasm for TUMJA and for her continuous support and constructive feedback.

Finally, we would like to thank TUMJA for this great experience that brought us together from different backgrounds. The encouragement and constant inspiration motivated us to embark on this beautiful journey and achieve our goals.


Junge
Akademie

POSTER 3:

Right from the beginning of the program, our team wanted to collaborate on a topic related to sustainability. Sustainability being a very broad theme, we quickly had to narrow this down quite drastically. Waste separation had always been one of the recurring topics in our discussions. After talking with representatives from the Green Office in Weihenstephan, we eventually decided to look into the waste separation behavior at various campuses of TUM. The lack of uniformity in waste separation opportunities sparked our interest and we wanted to look into its current status-quo. The Green Office plans to implement various measures to improve waste separation behavior TUM-wide, and we wanted to inquire of students and employees what they thought would be of most benefit. Our research questions were thus condensed down to: To what degree is waste separated at different TUM campuses? and Which measures should be introduced to improve waste separation? In order to investigate these questions, we decided to conduct an online survey aimed at students and employees of TUM following the analytic hierarchy process (AHP) framework to reveal the relative preferences for different benefits of a campaign on trash segregation. Our project started in November 2022 and we managed to gather data by mid-March 2023 to conduct the mentioned analysis in April 2023. ■



POSTER 4:

We gathered approximately 170 responses from TUM students and employees, and we analyzed the data using two methods: the analytical hierarchy process (AHP) and compositional data analysis (CDA). CDA helped us understand the current state of waste separation behavior at TUM, while AHP was used to evaluate different measures for improving waste separation.

Our survey revealed a gap between the acceptance and actual practice of waste separation at TUM campuses. Limited availability of multi-purpose waste bins and a lack of awareness about waste bin color schemes contribute to the challenges faced by TUM members. The existing "Wertstoffinseln" stations are ineffective in promoting waste separation. Improved collection of separated waste is crucial, so this ineffectiveness indicates deficiencies in the current waste management system. Information and awareness campaigns are considered less important overall and at specific campus or school levels. Addressing these issues is vital for promoting effective waste separation practices at TUM.

In collaboration with the facility management, the Green Office has implemented the first measure, which is an organized color scheme for proper waste separation. Low acceptance of waste separation is a problem of the past. We encourage further measures to be implemented in the future, aligning sustainability with excellence. ■