Public Summary

Creating insights, KPIs, visualizations and a dashboard of the operational residual streams' performance regarding the circularity goals of Company X.

December 25th, 2022

Max Miedema
S2254565
m.n.g.miedema@student.utwente.nl

UNIVERSITY OF TWENTE.

UNIVERSITY
OF TWENTE.

Public summary

Creating insights, KPIs, visualizations and a dashboard of the operational residual streams' performance regarding the circularity goals Company X has set for 2030.

Student:
M.N.G. Miedema (Max)
s2254565
Bachelor Industrial Engineering and Management

Supervisors:
University of Twente

First supervisor:
Dr. P.B Rogetzer (Patricia)
Assistant professor
Faculty of Behavioral, Management and Social Sciences (BMS)

Second supervisor:
Dr. rer. nat. D. Braun (Daniel)
Assistant professor
Faculty of Behavioral, Management and Social Sciences (BMS)

Company X
Anonymous

University of Twente
Industrial Engineering and Management
Postbus 217
7500 AE Enschede
Tel. (053) 489 9111

Publication date original thesis: 08-09-2022

This report was written as part of the bachelor assignment of the Industrial Engineering and Management educational program at the University of Twente.

Public Summary

Problem objective and goal

Company X has set goals to achieve some sustainability goals by 2030. Company X does not yet achieve the goal of zero waste for their operational waste streams. Company X currently uses a simple dashboard in PowerBI where the Key Performance Indicators (KPIs) used in the dashboard only show the current state of the waste streams, based on the total amount of the waste and how well a waste stream is separated. However, these KPIs are not specific/detailed enough to highlight weak spots within Company X and the reason/calculations behind these numbers. Company X wants to base its actions toward circularity for these operational waste streams, also called operational residual streams, on a new dashboard, but specific and measurable KPIs with appropriate visualizations regarding their circularity plans are missing. Therefore, the research objective is *to provide insights and use them to come up with KPIs, visualizations and a dashboard of the operational residual streams regarding Company X's circularity goals.*

Research questions

1. **What is the current situation of operational residual streams (what important facts can we deduct)?**
    - 1.1 Which KPIs are currently used to measure the performance of the operational residual streams?
    - 1.2 What is the current situation over all operational residual streams combined? (Company X in general)
    - 1.3 What is the current situation of the operational residual streams in each business unit?

First, we analyse the current situation. We analyse the data in general and per business unit and conduct interviews. We give an overview of the problems regarding the residual streams that Company X and the different business units are facing and highlight important parts to improve on circularity within the streams, which help choose KPIs.

2. **What are appropriate KPIs and visualizations for the operational residual streams according to literature?**
    - 2.1 On which criteria should we select the KPIs?
    - 2.2 What method should we use for KPIs selection?
    - 2.3 Which visualization types can be useful to visualize the KPIs?
    - 2.4 How to visualise a dashboard?
    - 2.5 Which KPIs are used for monitoring circularity goals regarding operational residual streams in literature?

Second, we conduct a systematic literature review to find performance KPIs regarding residual streams in combination with circularity, currently used by other companies or in research. KPIs in literature might be valuable for Company X to measure its goals. Moreover, we describe methods used in literature and choose a method together with criteria set which we both use to decide on the final KPIs. Furthermore, we conduct a literature search on visualization types for KPIs, get an overview of them and their usage and investigate how to best visualise a dashboard.

3. **What are the needs and should be the KPIs of Company X in general regarding the operational residual streams?**
    - 3.1 What are the main goals of Company X regarding their operational residual streams?
    - 3.2 Which KPIs can make these goals measurable?
    - 3.3 How to select the final KPIs?
    - 3.4 How does Company X perform regarding the main goals?

Third, we select the KPIs for monitoring the general performance of the circularity goals of operational residual streams, we also use information gathered in research question two for this. We have some meetings and presentations with essential stakeholders to receive preferences, feedback, and more insights to develop the best possible KPIs for the general measurement.

4. **What are the needs and should be the KPIs of Company X's business units regarding the operational residual streams?**
    - 4.1 What are the main goals per business unit regarding the operational residual streams?
    - 4.2 Which KPIs can make these goals measurable?
    - 4.3 How to select the final KPIs?
    - 4.4 How does each business unit perform regarding the main goals?

Fourth, we select the KPIs for each business unit. It starts with interviewing relevant stakeholders at the business units and using the obtained information about the current situation to define the main goals. The iterations by having meetings and giving presentations to the important stakeholders create feedback, preferences, and more insights to develop the best possible KPIs that suit the business units.

5. **What is the best suitable way to visualize each KPI?**

Subsequently, we choose the visualization type that is best suitable for a certain KPI. We combine the KPIs obtained by research questions 3 and 4, together with the literature study of research question 2. The goal of each visualization type must be clear. This should make sure that the interpretation of the data is correct.

6. **How to structure the KPIs and visualisations to develop a PowerBI dashboard?**

We present the different KPIs and their visualisations and create a layout of the dashboard that looks as organised and clear as possible. We use the information obtained from research question 3.4 together with the KPIs and visualisations of research questions 4 and 5 to create the dashboard in PowerBI. Furthermore, we follow online Microsoft PowerBI courses.

Approach

We conduct data analysis to give insights into the current situation of the operational residual streams together with the performance of the operational residual streams on the existing KPIs. We do this for both Company X in general and each business unit (BU). The business units of Company X are BU1, BU2, BU3, BU4 and BU5. We conduct a literature review on KPIs currently used in similar situations, visualisation types for the KPIs, the visualisation and structure of a KPI dashboard, a KPI selection method and criteria sets to use in a KPI selection method. We set specific targets for the operational residual streams based on the overall circularity goals of Company X and set up a list of potential KPIs for Company X in general. Moreover, we use a self-created criteria set based on literature and use this set with the AHP method to select the final KPIs. The targets of the business units are the same as the targets of Company X in general since all business units together work towards the same overall goals of Company X. However, not the same KPIs apply to all the business units. The KPIs expressed per customer do not make sense within each business unit. Only for the business unit BU2, where the department DP8 makes up more than 90% of the total waste every year and contains waste mainly caused by customers.

Literature search

Criteria set

Based on the selection and combination of relevant criteria for this thesis, we create a new list of seven criteria created that we would use to select the final KPIs. Table 1 shows these criteria.

Criteria	Meaning
Relevant	The degree to which the KPI enables performance improvement in the target operation (the goal). The KPI should contribute to the goal and targets the KPI intents to measure.
Traceable	The degree to which the steps to fix a problem are known, documented, and accessible, where the particular problem is indicated by values or temporal trends of the KPI. It should be clear how to act in order to improve the KPI.
Independent	The degree to which the KPI collection, transfer, computation, implementation, and reporting are performed independently from process stakeholders.
Accurate & Measurable	The degree to which it is possible to measure the exact true value of the KPI.
Time-Bound & Predictive	The degree to which it should be possible to predict a value over time based on past performances of the KPI. And therefore, also the degree in which it is possible to measure the KPI over time.
Understandable	The degree to which the meaning of the KPI is comprehended by team members and management, particularly concerning corporate goals.

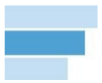
Table 1: Criteria set

Model decision

For this thesis, we decided to use the AHP method as the MCDA method to select the KPIs. The advantage of AHP over another possible model to use, the KAM method, is that within the AHP method, the pairwise comparison makes it possible to determine how much some KPI is better than others, whereas the KAM method only uses an order given by the stakeholders, which does not show how much better a KPI is better than another. Moreover, the KAM method is for defining KPIs in manufacturing processes. The AHP method is more general and finds its usage in a wide variety of sectors. Therefore, the AHP method suits our KPI selection process better than the KAM method.

Visualisation methods

Visualization type	Visual	Choice of explanation/ Application Area
Situation: When only one number is of importance.		
Showing the big number		If there is only one important number to remember, then it is convenient to show this number big, as just the number/ value or percentage. Often used for visualization of probabilities with natural ratios.
Icon arrays		If a proportion/percentage needs to be accurately interpreted. Sometimes the number is hard to put in perspective, especially for people with lower numeracy skills. Using icon arrays in combination with e.g., just showing the big number, will make sure the number will be interpreted correctly.
Donut or pie charts		Donuts or pie charts are used to visualize a percentage/ proportion. Since it is hard to interpret the angle of the chart, it is better to use it in combination with a single number showing the value as well. The pie chart is best used to show a simple share of the total in static compositions.

Highlighted bar graph		Most of the time, bar graphs are used to visualize multiple data, but bar graphs can still rework themselves to support the visualization of a single number. A way to highlight a single number in a bar graph would be by, for example, turning down all the colours on the bars except for the bar that needs attention. This helps the viewers of the chart to remember a single number, while also, the ratio/proportions are visible.
Situation: When visualizing two of more number's alikeness or difference.		
Side-by-side column or bar chart		This visualization is the most ubiquitous way of comparing and visualizing two or more numbers. Although their wide usage, they have significant limits on their effectiveness. According to Talbot et al. (2014) it is difficult to compare between nonadjacent bars, bars to compare should therefore always be adjacent. On top of that, Cowan (2020) says that our brain can only progress groups of three to five. Thereby, within these (small) groups, bar charts are preferable when the comparison is between many items, and a column chart is used when there are just a few items to show.
Slope graph		Slope graphs are best used in situations to show how one category increased while other categories decreased. Moreover, they can show the rate of change of a certain category compared to others. Humans are good at detecting slopes, therefore, this visualization type can be helpful in situations where a rate of change of a category compared to others needs to be visualised.
Back-to-back bars		This visualization method is usable when there is a comparison of non-specific values. When values need to be specific, it is hard to compare the two bars, since this visualization method makes use of mirroring. That is why this visualization is used for showing, for example, the overall shape of some data or natural distributions/ bell curves in two datasets and since humans tend to like symmetry, this visualization method can be preferable.
Dot plot		According to Jacoby (2006), humans are more accurate at interpreting dots on a line instead of judging a length, in for example, a bar chart. Dot plots can be a nice alternative for visualizing differences between two or more numbers in a less conventional way.
Small multiples		When multiple data streams of categories get compared in the same graph, it may happen that this is too much information to comprehend. In these cases, small graphs of the same visualization type (small multiples), for example, next to each other, can help to make the information visualization more comprehensible.
Situation: When visualizing data compared to a benchmark/target		

Benchmark Line		Visualizing data by adding a benchmark line gives the visualization a lot more context. It gives more meaning to the visualization to make a comparison with the target/benchmark easily visible.
Combo Chart		When the target/benchmark changes over time or depends on other values, a combo chart can show the different data compared to the also changing target/benchmark over, for example, different years.
Bullet Chart		These visualizations mode is best applied when the data can score in different categories (targets). Often, the vertical line in the chart represents the actual value of the data shown and the different colours on the background represent the range like, bad, good, excelled where the value is in.
Indicator dots		Indicator dots show whether a target has been met. Indicator dots are best used when relative performance to a target is not important.
Situation: When percentages or proportions are shown. (excl. already mentioned pie/donut charts)		
Stacked bar		As mentioned, lengths are easier to compare than angles. So, the bar chart can be a good alternative to the pie/donut charts. It shows the proportion of a whole of different categories in the bar. However, when visualizing many categories into the bars, it will be impossible to read and other options need to be considered.
Histogram	 	A histogram is best used for binned quantitative data. Where binning is a technique for grouping a set of more or less continuous values into a smaller number of bins (intervals), which can, for example, be used as visualization for income intervals within a country.
Three maps		Three maps represent parts through rectangular shapes within one big rectangular. Three maps are useful for showing the hierarchy, which makes them sometimes preferable to choose.
Situation: When values change over time		
Line chart		The most obvious way to visualize change over time is by expressing the change by a line. Since people are familiar with using lines to visualize changes that occur over time, and it is used most of the time, a line chart may be the way to go in this situation. The 2010 American Psychological Association (APA) Style Guide recommends not to use more than 4 lines per graph.

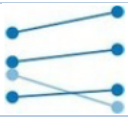
Stacked column/bar chart		Since line graphs do not really give a lot of visual weight to each quantity of the lines, line charts can be inconvenient to use. Since some changes are not easy to see or are unclear in size, bar charts can be the best option in these situations.
Deviation bar		Sometimes, when it is only important how much change has occurred since the beginning, a deviation bar graph is the way to show this. Most of the time the left side of the bar is used for negative values and the right side for positive. An example of the most famous use for the deviation bar is the turnover of companies.
Slopegraph		The slope graph can also be used to visualize changes over time. It can show different categories performing to each other between two timeframes.
Sankey		The visualization mode Sankey is best used to show the flow over the time between different categories as well as showing their quantities by the thickness of the lines.

Table 2: Chart types and usage
(Based on: Costa & Aparci, 2019; Evergreen, 2016; and Cleveland & McGill, 1984)

Dashboard Visualisation

Screen Graphics and colours.

Screen graphics and colours are important "in building the visual framework of the dashboard"(Malik, 2005, p.45). The colours of the banners, navigation tabs, and borders within a dashboard should preferably be light and neutral. They should not distract themselves from the key message and information that the dashboard shows. Colours like light blue, light grey or light beige are preferable (Malik, 2005). Bera (2016) mentions that misuse and overuse of colours lead to a more comprehensive discussion-making process, the dashboard creator should, therefore, always try to avoid this. Last, Bugwandeen & Ungerer (2019) mention that colour coding within the dashboard indicates the performance, where red indicates poor, green good and orange medium.

Dashboard layout

First, Bugwandeen & Ungerer, 2019 mention that the dashboard should be easy to read, where all the information in the dashboard is clear and therefore should be simple. The dashboard information should be visible and ''pushed to the user without their active participation"(Janes et al., 2013, p.21). Moreover the user of the dashboard does "not need to interact with visualizations to understand the data" (Janes et al., 2013, p.21). Hence every visualisation should have a purpose of its own. The dashboard should always be one well-designed screen, enabling the user to get all the information just in one glance (Eckerson, 2011). Most dashboards consist of multiple windows (frames) within the dashboard screen. (Malik, 2005) mention that four frames are optimal and that there should not be more than six frames, this will prevent the data becomes overwhelming. Suppose that graphs, visualised next to each other, within these frames consist of the same unit in the axis, then the X-and Y-axis should have the exact same axis length (Bhatt, 2017), to have a symmetric dashboard.

Moreover, the space between the objects and the edge of the screen should be constant. "Several scientific studies prove that symmetry is more eye-catching."(Bhatt, 2017, p.98)

Within the windows and the general layout of the dashboard, the training course PowerBI of Microsoft mentions that the placements of objects within the dashboard are important. A dashboard should display

the most critical information, in our case one of the KPIs, in the upper left corner. We should then arrange elements within the dashboard from left to right and top to bottom.
If there is a need for multiple dashboards, the dashboard creator can make those within one program using tabs. Malik (2005) mentions that tabs, that allow users to navigate across related dashboards, are "presented horizontally or vertically with a brief title on which the user may click to see the corresponding dashboard" (Malik ,2005, p.56). Within the different pages of the dashboard, it should ensure consistency. Recurring objects, such as logos and text boxes, should also have the same position within different dashboards in the different tabs (Bhatt, 2017), including the fonts and colours (Bugwandeen & Ungerer, 2019). (Eckerson, 2011) supports this and explains that next to tabs, a dashboard should also contain specific filters to manage information. (Malik (2005) calls this a Drill-Down function for the source, where filters should be present to select particular data points of a specific graph, e.g., the years in which the graph should show the data.

KPIs in literature

We can divide waste streams related KPIs regarding circularity into waste composition, recovery, logistics, and costs. Waste composition focuses on KPIs of the total amount of waste and the impact of this waste. KPIs of the recovery category make it possible to monitor the implementation of waste handing based on the 10R framework of Potting et al. (2017) and make it possible to improve the circularity per stream based on this framework, which covers the key concepts for creating a circular environment within the waste streams. Third, we should implement the total impact of the waste streams as a KPI because otherwise, it would be impossible to decrease the total emissions. To do this, it is important to take all the logistics around the handling of the waste streams into consideration to come up with KPIs that show these emissions as well as the emissions of the waste handling itself. Next, costs of waste handling is an important KPI to implement, both in total as on some waste streams separately, however, this will be outside the scope of this research. To monitor the waste streams regarding the circularity goals over time, the KPIs should the expressed in absolute terms like, per person or unit. By defining KPIs later, we should keep in mind that if we use the found KPIs by this literature search and/or KPIs obtained or made up by, e.g., an interview, we must express the KPIs in the correct way that allows monitoring over time, for example, emissions per customer or amount of waste per customer.

Results

The AHP method together with our self created criteria set based on literature gave the following KPIs for Company X in general and each BU.

The KPIs for the business unit BU2 and Company X in general, with their targets, are:

- ***Total residuals produced per customer – based on weight***
  The target is a 30% reduction based on its 2019 value.
- ***CO_2 emissions produced per customer***
  The target is a 50% reduction based on its 2019 value.
- ***Percentage of total residuals incinerated (excl. confidential material)***
  The target is 1% or lower.
- ***Total CO_2 emissions per weight of waste***
  The target is a 50% reduction based on the 2019 value of Company X in general for both Company X in general and BU2.

And for the remaining business units the KPIs, with their targets, are:

- ***Total weight of waste***
  No target.

- ***Total CO_2 emissions***
  No target.
- ***Percentage of total residuals incinerated (excl. confidential material)***
  The target is 1% or lower.
- ***Total CO_2 emissions per weight of waste***
  The target is a 50% reduction based on the 2019 value of Company X in general, for all business units.

Moreover, we provide new insights into the performance regarding the new KPIs, and some new general insights based on newly obtained data and information during the research.
Based on the literature, the best visualisation method is a column chart with a benchmark line/target for the four KPIs with a target value. The visualisation type for the two KPIs without a target value is "showing the big number", so it just shows the number without a graph.
Next, we provide the dashboard consisting of these KPIs and visualisations. The dashboard consists of five different tabs (pages), one for every business unit and one for Company X in general. Each page shows the two KPIs without target value as a big number on the top banner. For Company X in general and the business unit BU2, the dashboard page has four frames, and for the remaining business unit, the dashboard has two frames, demonstrating all the KPI values with target values in a column chart with a target line.

Validity check of the results

We must ensure consistency in the whole AHP method process to secure a valid result, so we should check the consistency for every pairwise comparison that is made within the AHP method. When the consistency ratio is smaller than 0.10 for all the comparisons, we can secure a correct result without inconsistencies. Table 3 shows that all the consistency ratios of the pairwise comparisons within the AHP method are smaller than 0.10 and thus ensuring consistency.

Pairwise comparison of the	**Consistency ratio (CR)**
Criteria against the criteria	0.015
Criteria Relevant	0.088
Criteria Traceable	0.053
Criteria Independent	0.078
Criteria Accurate and Measurable	0.080
Criteria Time-Bound	0.056
Criteria Understandable	0.031

Table 3: Consistency ratios of all the pairwise comparisons within the AHP method

Conclusion and recommendations

We can conclude that we fulfilled the norm in the new situation after the research. The dashboard that we created within PowerBI gives business unit dependent KPIs and visualisations. Moreover, the different tabs of the dashboard make it possible to see the performance of the different business units and derive where Company X needs to focus the most. The KPIs have a target value and are measurable over time; it is possible to monitor the performance of each business unit and for Company X in general. Last, the visualisations of the KPIs help interpret the data by showing the target and the performance in one graph. Finally, we recommended Company X to:

- Make more waste separation possible. We recommend Company X to make more separation options possible within more business units and throughout the whole business unit. Moreover, creating a standard way of separation throughout all the business units would help.
- Look into post-separation of residual waste to increase separation. Post-separation is the separation of the residual waste after it is already thrown away, so before the waste in handled by the waste handler. Post-separation ensures the waste within the residual waste is still separated within the other residual streams.
- Create more awareness of separation. Not only create awareness among the employees but also among the customers. Moreover, we advise the company to create more awareness among the department and business unit managers.
- Work with a waste hierarchy, that indicates how well (on the waste hierarchy) a waste stream is handled regarding circularity and try to implement it within the KPIs when the data is available. This indicates how Company X can improve the circularity on specific operational residual streams.
- Continually evaluate the KPIs over the years to keep the dashboard relevant.
- Remap all the operational residual streams within the different departments and business units to prevent errors within the dashboard like the old dashboard has.
- Still use the old main KPI, the separation rate, in the transitional period from the old to the new KPIs to provide a smooth transition without disrupting the employees' daily activities by making radical changes.
- Further research on the possibility to (partly) separate confidential material waste to increase separation.
- Further research on the possibility of switching from waste handler to get more data transparency and obtain data currently missing from the current waste handler.
- Further research on the possibility of implementing a visualisation within the dashboard for each KPI that indicates the direction the KPI value is heading regarding its target. This visualisation can be something like a traffic light system to see if the KPI value is improving and if Company X is on track regarding its circularity goals at one glance.
- Further research on the feasibility of the different KPI targets defined within this research or already defined before this research to see if these targets are realistic.

References

Al, K. M., & Al-Harbi, -Subhi. (2001). Application of the AHP in project management. International Journal of Project Management, 19, 19–27. https://doi.org/10.1016/S0263-7863(99)00038-1

American Psychological Association. (2010). Publication manual of the American Psychological Association (6th ed.). Washington, DC: American Psychological Association

Bera, P. (2016). How colors in business dashboards affect users' decision making. Communications of the ACM, 59(4), 50–57. https://doi.org/10.1145/2818993

Bešić, C., Đorđević, D. (2007) Benchmarking. Serbia, Čačak: Faculty of Engineering

Bhatt, S. (2017). How to visualize your business intelligence report - A research based study. International Journal of Advanced Research in Computer Science, 8(7), 97–103. https://doi.org/10.26483/ijarcs.v8i7.4298

Bugwandeen, K., & Ungerer, M. (2019). Exploring the design of performance dashboards in relation to achieving organisational strategic goals. South African Journal of Industrial Engineering, 30(2), 161–175. https://doi.org/10.7166/30-2-2021

Clark, B.H.; Abela, A.V.; Ambler, T. (2006): Behind the Wheel: Align Marketing Goals and Corporate Strategies through Dashboards, *Marketing Management*, *15*, 18-23. Retrieved from https://www.researchgate.net/publication/294135483_Behind_the_wheel.

Cleveland, W. S., & McGill, R. (1984). Graphical perception: Theory, experimentation, and application to the development of graphical methods. *Journal of the American Statistical Association*., *79*(387), 531–554. https://doi.org/10.1080/01621459.1984.10478080

Company X. (2019). ***This section can not be shown due to confidential reasons***

Company X. (2020). ***This section can not be shown due to confidential reasons***

Company X. (2021). ***This section can not be shown due to confidential reasons***

Costa, C. J., & Aparci, M. (2019). *Supporting the decision on dashboard design charts*. Paper presented at The IIER International Conference (2019). Retrieved from https://www.researchgate.net/publication/336680372_SUPPORTING_THE_DECISION_ON_DASHBOARD_DESIGN_CHARTS

Cowan, N. (2000). The magical number 4 in short-term memory: Are reconstruction of mental storage capacity. *Behavioural and Brain Sciences*, *24*, 87–185. https://doi.org/10.1017/S0140525X01003922

de Andrade, P. R. M., & Sadaoui, S. (2017). Improving business decision making based on KPI management system. *2017 IEEE International Conference on Systems, Man, and Cybernetics, SMC 2017*, 1280–1285. https://doi.org/10.1109/SMC.2017.8122789

del Borghi, A., Gallo, M., & del Borghi, M. (2009). A survey of life cycle approaches in waste management. *International Journal of Life Cycle Assessment*, *14*(7), 597–610. https://doi.org/10.1007/S11367-009-0111-7/TABLES/5

Eckerson, W. W. (2011). *Performance dashboards: Measuring, monitoring, and managing your business* (2nd ed.). Hoboken, NJ, USA: John Wiley & Sons, Inc.

Employee 1. (2021). *Circularity of Operational Residual Streams*. Internal Company X report: unpublished

Employee 1. (2022). ***This section can not be shown due to confidential reasons***. Internal Company X Excel file: unpublished

Employee 2. (2022). ***This section can not be shown due to confidential reasons***. Internal Company X Slideshow: unpublished

Evergreen, S. D. H. (2016). *Effective data visualization: The right chart for the right data*. Oaks, CA, USA: Sage

Few, S. (2006). *Information Dashboard Design: The Effective Visual Communication of Data*. Sebastopol, CA, USA: O'Reilly Media

Gosselin, M (2005). An empirical study of performance measurement in manufacturing organizations. *International Journal of Productivity and Performance Management*, *54*(5/6), 419–437. https://doi.org/10.1108/17410400510604566

Hester, P. T., Ezell, B., Collins, A., Horst, J., & Lawsure, K. (2017). A Method for Key Performance Indicator Assessment in Manufacturing Organizations. *International Journal of Operations Research 14*(4). Retrieved from https://www.researchgate.net/publication/321757397

Hester, P. T., Meyers, T. J., & Dupres, C. (2011, October). Towards a viable construct for R&D system governance. In *Proceedings of the 7th European Conference on Management, Leadership and Governance: SKEMA Business School, Sophia-Antipolis, France France, 6-7 October 2011* (189-198).

Horst, J., & Weiss, B. (2015). A Method for Effective and Efficient Selection of Balanced Key Performance Indicators. *National Institute of Standards and Technology, Washington, DC.*

Ishizaka, Alessio., & Nemery, Philippe. (2013). *Multi-criteria decision analysis : methods and software* (1st ed.). Chichester, West Sussex, UK: John Wiley & Sons, Inc.

Jacoby, W. G. (2006, June). The dot plot: A graphical display for labelled quantitative values. *The Political Methodologist*, *14*(1), 6–14. Retrieved from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.578.7483&rep=rep1&type=pdf

Janes, A., Sillitti, A., & Succi Giancarlo. (2013). Effective dashboard design. *Cutter IT Journal*, *26*(1), 17–26. Retrieved from https://www.researchgate.net/publication/286996830_Effective_dashboard_design

Kelleher, C., & Wagener, T. (2011). Ten guidelines for effective data visualization in scientific publications. *Environmental Modelling and Software*, *26*(6), 822–827. https://doi.org/10.1016/j.envsoft.2010.12.006

Keramitsoglou, K., & Tsagarakis, K. (2018) Public Participation in Designing the Recycling Bins to Encourage Recycling. *Sustainability MDPI AG*, *10*(4), 1240. http://dx.doi.org/10.3390/su10041240

Kerzner, H. (2011). *Project Management Metrics, KPIs, and Dashboards: A Guide to Measuring and Monitoring Project Performance*. Hoboken, NJ, USA; John Wiley & Sons.

Malik, S. (2005). *Enterprise dashboards design and best practices for IT*. Retrieved from https://www.semanticscholar.org/paper/Enterprise-Dashboards%3A-Design-and-Best-Practices-IT-Malik/7e3416db310b68df550cd13c517d20ef24b46eab

Manfredi, S., & Goralczyk, M. (2013). Life cycle indicators for monitoring the environmental performance of European waste management. *Resources, Conservation and Recycling*, *81*, 8–16. https://doi.org/10.1016/J.RESCONREC.2013.09.004

McNeeney, A. (2005, April 1). Selecting the Right Key Performance Indicators, *Efficient Plant*. Retrieved from http://www.mt-online.com/ april2005/selecting-the-right-key-performance-indicators?Itemid=90>

Microsoft. (n.d.-a). Dashboard in a Day Power BI Training | Microsoft Power BI. PowerBi Microsoft. Retrieved July 12, 2022, from https://powerbi.microsoft.com/en-us/diad/

Microsoft. (n.d.-b). Power BI on Microsoft Learn: Microsoft Docs. Retrieved July 12, 2022, from https://docs.microsoft.com/en-us/learn/powerplatform/power-bi?WT.mc_id=powerbi_landingpage-marketing-page

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling, 153.* https://doi.org/10.1016/J.RESCONREC.2019.104553

Mu, E., & Pereyra-Rojas, M. (2017). *Practical Decision Making: An Introduction to the Analytic Hierarchy Process (AHP) Using Super Decisions V2* (3rd ed.). Pittsburgh, PA, USA: Springer.

Parmenter, D. (2010). *Key Performance Indicators (KPI): Developing, Implementing, and Using Winning KPIs* (2nd ed). Retrieved from https://books.google.nl/books?id=sLP_ipWrfssC&pg=PA4&dq=KPI&hl=en&sa=X&ved=2ahUKEwiyotzx59n3AhWHhv0HHXUwBmIQ6AF6BAgDEAI#v=onepage&q=KPI&f=false

Partner 1. (2022*).* ***This section can not be shown due to confidential reasons****, Sustainability project Company X*. Internal Company X report: unpublished

Podgórski, D. (2015). Measuring operational performance of OSH management system – A demonstration of AHP-based selection of leading key performance indicators. *Safety Science*, *73*, 146–166. https://doi.org/10.1016/J.SSCI.2014.11.018

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: measuring innovation in the product chain: Policy Report*, PBL Netherlands Environmental Assessment Agency (Report no. 2544). The Hague, NL: PBL Publishers

Radovic, M., Karapandzic, S. (2005) Process Engineering, Faculty of Organizational Science, Beograd.

Robbins, N. (2005). *Creating More Effective Graph*. Michigan, USA: Wiley

Saaty, T. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, *15*(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5

Shahin, A., Mahbod, M.A. (2007). Prioritization of key performance indicators. An integration of analytical hierarchy process and goal setting. *International Journal of Productivity and Performance Management*. *56*(3), 226–240. https://doi.org/ 10.1108/17410400710731437

Strange, N. (2007). *Smoke & Mirrors: How to Bend Facts & Figures to Your Advantage*. London, UK: A&C Black Publishers

Suhi, S. A., Enayet, R., Haque, T., Ali, S. M., Moktadir, M. A., & Paul, S. K. (2019). Environmental sustainability assessment in supply chain: An emerging economy context. *Environmental Impact Assessment Review*, *79*. https://doi.org/10.1016/J.EIAR.2019.106306

Talbot, J., Setlur, V., & Anand, A. (2014). Four experiments on the perception of bar charts. *IEEE Transactions on Visualization and Computer Graphics*, *20*(12), 2152–2160. https://doi.org/10.1109/TVCG.2014.2346320

Umor, N. A., Ismail, S., Abdullah, S., Huzaifah, M. H. R., Huzir, N. M., Mahmood, N. A. N., & Zahrim, A. Y. (2021). Zero waste management of spent mushroom compost. *Journal of Material Cycles and Waste Management 23(* 5), 1726–1736. https://doi.org/10.1007/s10163-021-01250-3

United Nations. (2015). *Paris agreement*. Retrieved from: https://unfccc.int/sites/default/files/english_paris_agreement.pdf

University of Twente. (2020a). *B1-3: Starting a search* [Video]. Vimeo. Retrieved from: https://vimeo.com/showcase/7471764/video/451436174

University of Twente. (2020b). *B1-4: Continuing a searc*h [Video]. Vimeo. Retrieved from: https://vimeo.com/showcase/7471764/video/451435045

University of Twente. (n.d.). Literature guide for Industrial Engineering and Management | Service Portal | University of Twente. Retrieved June 14, 2022, from https://www.utwente.nl/en/service-portal/university-library/find-access-literature/guides-per-discipline/industrial-engineering-and-management

Wang, L., Wang, G., & Alexander, C. A. (2015). Big Data and Visualization: Methods, Challenges and Technology Progress. *Digital Technologies,* 1(1), 33–38. https://doi.org/10.12691/dt-1-1-7

WHandling. (2022). ***This section can not be shown due to confidential reasons***. Internal Company X Excel file: unpublished

Yano, J., & Sakai, S. I. (2015). Waste prevention indicators and their implications from a life cycle perspective: a review. *Journal of Material Cycles and Waste Management*, *18*(1), 38–56. https://doi.org/10.1007/s10163-015-0406-7

Zwetsloot, G. (2013). *Key performance indicators*. In *OSH wiki, European Agency for Safety and Health at Work*. Retrieved April 5, 2022, from http://oshwiki.eu/wiki/Key_performance_indicators