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ICT in Business and the Public Sector

Centralisation and Decentralisation of Software Applications in a Multinational Enterprise: A Multi-Criteria Decision-Making Model

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MASTER'S THESIS

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Abstract

Introduction

The globally emerging need for digital transformation has led companies to increase the frequency of software decisions. As a result, companies need to decide whether to use multiple applications, standardise them, or use a hybrid approach within their organisation. There can be numerous factors that need to be taken into account while making such a decision.

Objectives

The main objective of this study is to provide a decision-making model that can guide enterprises while deciding whether to centralise or decentralise software applications. This study also aims to find the factors affecting this decision to design the intended decision-making model.

Methods

In this research, a mixed research methodology is used. This research used design science and case study methodologies to answer the research questions and develop the decision-making model. Then workshops are performed among four workshop groups to test the decision-making model. Lastly, a questionnaire is conducted with the workshop participants to evaluate the model's success.

Results

The results of the study are gathered from two sources. First, we gathered the data from the workshops. Second, data is gathered from the questionnaire that aimed to measure the model's success. After collecting the data, results are visualised by several graphs and tables.

Conclusion

Based on the study’s findings, we concluded that the designed MCDM model is successful in facilitating (de)centralisation decision-making. The designed MCDM model provides a collaborative, user-friendly, easy-use model that increases the decision-makers' confidence and comfort. The study results and the reviewed literature align regarding the factors that affect this decision. The determined factors are as follows: Innovativeness, flexibility, IT support, integration ability, collaboration ability, and IT cost.

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Acronyms

EoS – Economies of Scale

CBA – Cost Benefit Analysis

SAFe – Scaled Agile Framework

MCDM – Multicriteria Decision Making

WSM – Weighted Sum Model

AHP – Analytical Hierarchy Process

FAHP – Fuzzy Analytical Hierarchy Process

ELECTRE – Elimination and Choice Translating Reality

VIKOR – Visekriterijumsko Kompromisno Rangiranje

TOPSIS – Technique for Order of Preference by Similarity to Ideal Solution

KHC – Kraft Heinz Company

SW – Software

1. Introduction

Digital transformation in companies increased the frequency of software decisions. As a result, companies need to continuously decide whether to use multiple software applications, standardise the applications, or use a hybrid approach for the same task in the enterprise (Sklyar et al., 2019). The best decision varies between different enterprises.

Digital transformation is switching traditional business operations to digital technologies to optimise the value-generation process (Vial, 2019). IT departments mainly aim to centralise the technologies used in their company (Louis et al., 2001). There are various reasons behind this decision. The first reason is the difficulty of managing and providing IT support to multiple software applications (Sklyar et al., 2019). When the software applications are standardised, there are more users of that application. It is always easier to develop solutions or new features for applications with more users (Akkermans et al., 2002). However, the most significant benefit of centralised software applications is lower technology costs by up to 50% compared to using multiple applications in a company due to economies of scale (Louis et al., 2001). The centralisation of software applications also creates a more collaborative environment. Since the employees use the same software, it is easier for them to work with each other. This is not the case for decentralisation. It is a challenge for people who use different applications to collaborate, and most of the time, it is not even possible (Akkermans et al., 2002).

Although centralising software applications is a popular option, it may not be the best decision for every company. Most of the time, it is not even possible to centralise software applications due to constantly changing software needs (Akkermans et al., 2002). The centralisation of applications may limit the innovativeness of the company. Even though the applications might be similar according to their field of use, they still provide different features, and it is beneficial for a company to use those different features (Nell et al., 2021). While centralised software applications provide more control, are cost-efficient and easier to support by the IT department, it is not as flexible. This raises issues since a company's industry can be unpredictable and rapidly changing. In order to follow up with the changes, more software applications might be necessary (Magnusson, 2013). Standardisation of the applications may limit the ability to react to the changes.

There is no one-size-fits-all decentralisation or centralisation decision for the companies (Akkermans et al., 2002). However, it is possible to know the factors that should be considered while making this decision and use those factors when making a centralisation or decentralisation decision. If businesses can use a decision-making model involving those factors, they can make their decisions more comfortably and confidently. In addition, a decision-making model can justify the enterprises after the decision is made.

1.1. Problem Definition

Even though organisations tend to aim for centralisation to use economies of scale and ease of management, this is not always the most optimal nor possible option for every situation. The company might need different features for certain operations, or there might be various local needs. Therefore, it is challenging for companies to decide whether to centralise or decentralise software applications.

In addition to the difficulties in making this decision, it is also difficult to justify it. The decision maker(s) should be able to explain why they made the specific decision.

1.2. Objectives of the Study

The study's objective is not to find the "best" structure for software application usage since no single model fits all. This study aims to provide a decision-making model to make decisions comfortably and confidently and justify the final decision.

The second objective of this study is to determine the criteria for deciding whether to centralise or decentralise software applications.

1.3. Research Question

As explained in the Objectives of the Study, this study aims to develop a model to assist companies' while deciding whether to centralise or decentralise the software application and find the criteria that affect this decision. The following research questions are determined based on the aim of this research. The research questions will be answered throughout the paper to reach the study's objectives.

- RQ1: "Can a model be developed to support such multi-criteria decision-making regarding software applications?"
- RQ2: "What factors affect the decision-making of centralisation or decentralisation of the software applications used in a multinational company?"

1.4. Deliverables

The deliverables of this study are the outcomes of the conducted research. These deliverables are;

Decision-Making Model: The main deliverable of this research is a decision-making model that can guide organisations when making software application decentralisation/centralisation decisions.

Questionnaire Data & Analysis: As mentioned in the Research methodology part, data will be collected through questionnaires. The questionnaires and the outcome analysis will be provided as a result of the research.

1.5. Thesis Outline

The paper is structured as follows: In the first chapter, the thesis is introduced with an introduction, then the problem definition, objectives of the study, research questions and deliverables follow. In the second chapter, an extensive and detailed literature review is conducted to summarise the previous related studies. In the third chapter, there is the methodology part that explains the research design and research plan in detail. The fourth chapter of the study explains the model design. The fifth chapter examines the data collected and explains the research findings. In the sixth chapter, the results are interpreted, and the limitations of the study are discussed. Lastly, there is a conclusion for finalising the study.

2. Literature Review

This section includes an extensive and detailed examination of previous studies under three main titles. These three main titles are: (1) “Centralisation and Decentralisation” to explain the meaning of these terms in the literature. (2) “Decision-Making Models” for reviewing the models used in the previous studies and explaining their relevance to this study. (3) “Factors that affect this decision” for understanding the factors that should be considered while making the (de)centralisation decision of software applications that are being used. After the main titles, a “Summary” part follows to summarise and visualise the literature review to improve the ease of understanding.

2.1. Software Application (De)Centralisation

The terms centralisation and decentralisation are too vague. First, the meaning of these terms will be examined in the domain of this study. Then, these terms will be examined in the business scope to explain the general context.

In this research, the meaning of centralisation and decentralisation is not structural (de)centralisation. In this paper, “centralisation” refers to using a single software application in a company for the same task. “decentralisation” indicates using multiple software applications for the same task. Furthermore, “centralisation” indicates using only a single tool in the whole enterprise for the same task. In a hybrid approach, enterprises use both of the approaches. They have a centralised structure, but for some locations, teams or projects, they follow a decentralised approach (Brown et al.,1994).

According to Hage et al.. centralisation means distributing decision-making power among a company's departments, teams or employees (1967). If the decision-making power is primarily collected in a unit, then this company can be considered a centralised organisation compared to a company that distributes power relatively equally (Hage et al., 1967).

Moynihan also defines (de)centralisation similar to Hage et al. The definition of centralisation is the concentration of decision-making authority in a single person (Moynihan, 1985). One person is not liable for decision-making because different brains can know different situations that might affect the decision. Decentralisation is the state of decision-making by multiple individuals since centralisation is insufficient (Moynihan, 1985).

Supporting these two definitions, according to Jarzabkowski (2002), decentralisation and centralisation are two concepts that are used to define the structure of decision-making in a company. If the decisions are company-centric, meaning that the focus is on the company’s success and wellness, then this is centralisation. If the decision-making is done locally, this is decentralisation

(2002). So these terms define the control of the management on the decision-making process (Jarzabkowski, 2002).

The power distribution among the units should be considered to measure the organisation's centralisation or decentralisation. Because according to Hage et al., centralisation and decentralisation are only about power distribution (1967).

2.2. Technology Decision-Making Models

The literature review is performed to discover a decision-making model that can be used in this study due to the lack of decision-making tools tailored for software application (de)centralisation. The expected outcome of this literature review is to find a decision-making model that we can modify and use for (de)centralisation decisions of software applications.

2.2.1. The Four Forces of Marketing Operations and Technology

According to Brinker (2018), four forces in the market challenge marketing operations in order to keep up with the changes in the rapidly changing environment. Those forces are technology, scale, speed and people, as shown in Figure 1. Since the other two forces are out of the scope of this research, the focus will be on speed and scale.

Brinker (2018) suggests that companies should use decentralisation and centralisation hybrid to use scale and gain speed to keep up with the changes in the market. As shown in Figure 1, organisations should centralise the tools as much as possible to achieve the benefits of the scale, such as taking advantage of EoS. However, at the same time, they should also decentralise as much as possible too to gain speed in the operations. Companies should centralise generally and decentralise for specific and local tasks (Brinker, 2018)

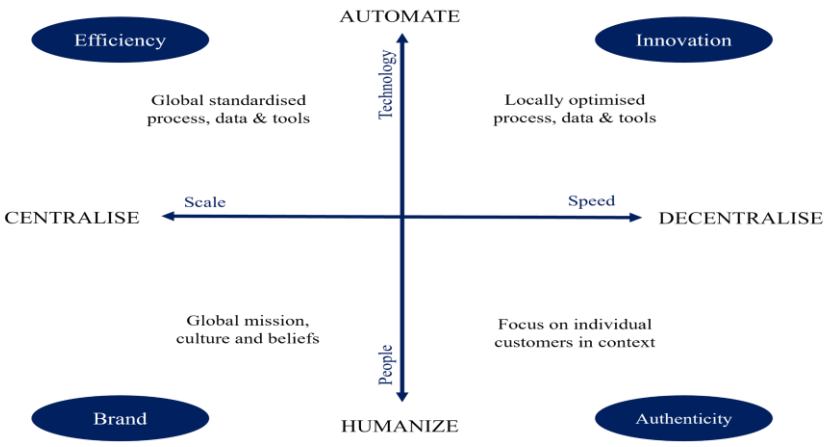

Figure 1:The four forces of Marketing Operation and Technology (Brinker, 2018)

2.2.2. Technology Decision-Making Approach

In the Technology Decision-Making Model, Ilori et al. suggest four inside and outside factors that affect an individual's decision-making process, as shown in Figure 2. The four inside factors are: (I) Rational analytics approach is the approach where the decision maker uses quantitative data for making the decision. In this approach, the decision maker has quantitative proof that can explain the decision. (II) Intuitive - emotional decision approach is based on experiences and the personal thought of the decision maker. (III) The political-behavioural decision approach is where the decision-maker is influenced by the stakeholders of the decision. (IV) The social and cultural approach suggests that the individual's personal background can affect the decision (Ilori et al., 1997).

The four outside factors are (I) Certainties of the environment where the decision-maker knows all the possible outcomes of the decision. (II) Uncertainties of the environment where the decision-maker does not know the outcomes of the decision and needs to assess them after the decision is made. (III) Pressure from colleagues. (IV) Risks of the decision (Ilori et al., 1997).

However, in this study, Ilori et al. (1997) evaluate the decision-making process at an individual level. That is why the factors that have been determined are the factors that affect an individual's decision rather than a company's decision. So, the model provides the factors that affect an individual's technology decision making process rather than a decision-making model. Also, the model's audience consists of many levels of employees in a company, including entry-level employees who most likely do not have the analytical data (such as cost information) of the company and do not have enough experience to conclude a reliable decision.

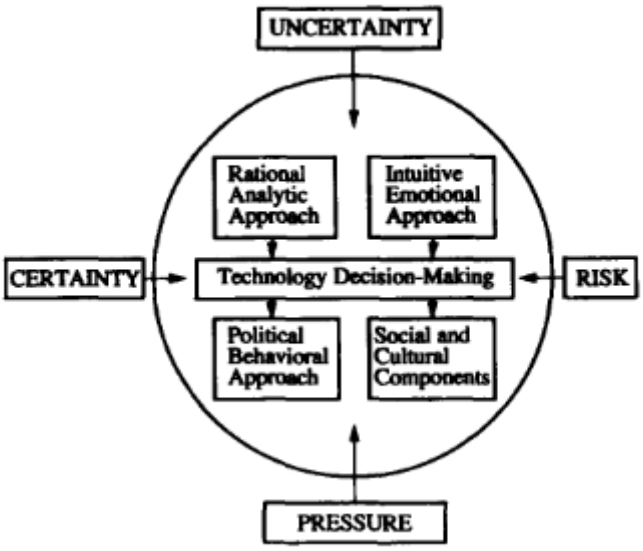

Figure 2: Technology Decision-Making Approach (Ilori et al., 1997)

2.2.3. IT Purchasing Framework

The IT Purchasing Framework explains the company's IT purchasing process and tendency to choose between centralisation/decentralisation of software based on IT relevance and purchasing maturity. IT relevance means the relation of IT to its core business functions. So if the application of IT is strategic to address a company's objectives, then the company's IT relevance is considered high (Luzzini et al., 2014). Purchasing maturity is a company's ability to manage the procurement process. If a company can manage this process efficiently, then the company's purchasing maturity is considered high (Luzzini et al., 2014).

This study explains IT as software; applications being used in a company and hardware; laptops, servers, keyboards etc. (Luzzini et al., 2014). Although this framework does not provide a decision-making model to decide whether to use centralised or decentralised software applications, it provides insights into how this decision is made.

According to this model, companies can be placed into four categories, presented in Figure 3, based on their IT strategic importance and purchasing maturity. These four categories are: IT Oriented, Neutral, IT Strategic and Purchasing Oriented. IT Strategic companies are the ones that IT plays a strategic role with high purchasing maturity. These companies will likely perform in the IT sector and have higher IT costs than others. These companies are more likely to have a centralised company structure and centralised IT tools. Neutral companies have a low purchasing maturity and do not consider IT as a strategic importance (Luzzini et al., 2014). In IT-oriented companies, IT functions are handled by IT specialists, and purchasing operations are still not at a maturity level. These companies tend to have a low centralised structure (Luzzini et al., 2014). In Purchasing Oriented companies, IT is not the core element of the business, and employees are not specifically IT-skilled. The purchasing maturity is high in those companies to have a competitive advantage (Luzzini et al., 2014). These companies have a highly centralised structure (Luzzini et al., 2014).

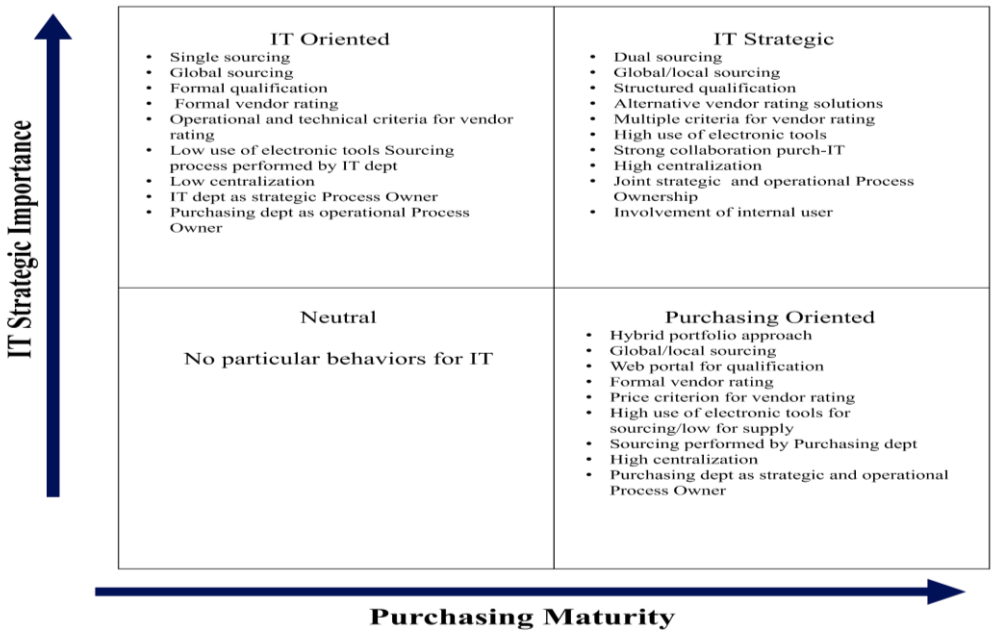

Figure 3: IT Purchasing Framework (Luzzini et al., 2014)

2.2.4. Cost-Benefit Analysis for Decision-Making

The Cost-Benefit Analysis (CBA) is a popular decision-making tool that involves economic evaluation. CBA quantifies the cost (input) and benefits (output) of an alternative and then compares these two values (Robinson, 1993).

According to CBA, a cost-benefit ratio is calculated for each alternative. The alternative with the highest cost-benefit ratio is considered the best alternative (Robinson, 1993).

$$\text{Cost-benefit Ratio} = \frac{\sum Present\ value\ of\ expected\ benefits}{\sum Present\ value\ of\ associated\ cost}$$

2.2.5. Take versus Delegate Thinking Framework

Take versus Delegate Thinking Framework is a decision-making tool created by the Scaled Agile organisation. SAFe is a widely used agile practice implementing framework. Its main aim is to provide an approach to adopt agile methodologies, mostly at large enterprises (Scaled Agile Inc, 2023). The main objective of this tool is to help decide (de)-centralisation decisions. The idea behind this tool is deciding (de)centralisation by answering if the determined criteria are essential for the objective (Oren, 2023). This model has three criteria: Frequency, time-critical, and economies of scale.

The decision-maker uses this tool by filling out the table provided by SAFe. This table can be examined in Table 1 below. First, the decision-maker fills the decision column by writing the specific

(de)centralisation decision that needs to be decided, such as "(de)centralising software applications". Then the decision-maker should ask if the given criterion is essential for the decision. For example, the following questions can be asked: Is this decision taken frequently? Is this decision time-critical, or can it be delayed? Will the decision provide EoS? The decision maker should mark the criterion as "YES" if the criterion is essential. Otherwise, the criterion should be marked as "No". The corresponding point to each marking is shown in Table 1. After marking each criterion, the total of corresponding points are calculated, and the decision depends on the total point. The tool suggests centralising if the total is lower than or equal to three. If the total point is more than three, then the organisation should decentralise the decision (Oren, 2023).

Table 1: SAFe Decision Making: Take versus Delegate Thinking Framework (Oren, 2023)

Decision	Frequent? Y=2 N=0	Time critical? Y=2 N=0	Economies of scale Y=0 N=2	Total

2.2.6. Multi-Criteria Decision-Making (MCDM) Models

Multi-criteria decision-making (MCDM) models are the models that aim to help individuals, teams or companies to decide on any situation that has more than one criterion to be considered. These models can be used if multiple factors affect the decision (Anysz et al., 2020). According to Mardani et al., MCDM models are the most common and well-structured way of decision-making (2017).

This model's aim is not to find the ideal choice; if there is an ideal choice, then a decision-making model will not be needed to facilitate this process. Instead, the ideal option can be selected directly (Anysz et al., 2020). MCDM intends to evaluate the current options while deciding, not creating options and selecting the best alternative among these options. While using an MCDM, it should be clear that almost all alternatives include adverse effects and dissatisfaction (Pavan et al., 2009).

Since there are more than thirty MCDMs, it is only feasible to examine some of them (Mosadeghi et al., 2012; Mardani et al., 2015). Therefore, for the simplicity of this study, only six models are selected for consideration depending on their popularity and compatibility with the study. The chosen models taken into consideration to be used in this study are;

- WSM (Weighted Sum Method)
- ELECTRE (Elimination and Choice Translating Reality)
- TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)
- VIKOR (Visekriterijumsko Kompromisno Rangiranje translates to Multi-criteria Optimization and Compromise Solution)

- AHP (Analytic Hierarchy Process)
    - Fuzzy AHP

The selection of the model used is crucial because different models can deliver contrasting results. The reason is that every model has a different focus and rules for deciding (Hobbs et al.,2003). This does not mean that one model is better; however, the choice depends on the researcher and the research requirements (Lee et al., 2018).

2.2.6.1. Weighted Sum Model (WSM)

The weighted Sum Model (WSM) is the most common and basic MCDM model (Triantaphyllou, 2000). When deciding, according to this model, $options$ can be selected. Also, there are *n* weighted criteria that affect those options. A WSM score must be calculated to find the best option with maximum benefit (Triantaphyllou, 2000).

$$O_{\text{WSM-score}} = \max \sum_{j=1}^{n} O_{ij} W_j, \quad for\ i = 1, 2, 3, \ldots, m.$$

n: number of decision criteria

m: number of options

O_{ij}: the actual value of the i-th option

W_j: Weights of the options

An example is provided below to show how decisions can be made by using WSM. Table 2 provides an example of the WSM Matrix.

Table 2: WSM Matrix Example (Triantaphyllou, 2000)

	Criteria			
Options	C_1 (0.20)	C_2 (0.15)	C_3 (0.40)	C_4 (0.25)
O_1	25	20	15	30
O_2	10	30	20	30
O_3	30	10	30	10

To calculate the WSM score for making the decision, the calculations are as follows:

$O_{1,\ WSM\text{-}score}$ = 25 x 0.20 + 20 x 0.15 + 15 x 0.40 + 30 x 0.25 = 21.50

Option 2 and 3 can also be calculated by using the same formula;

$O_{2,\ WSM\text{-}score}$ = 22.00

$O_{3,\ WSM\text{-}score}$ = 20.00

The option with the highest WSM score makes the best decision (Triantaphyllou, 2000). In this example, the order of decision benefit is as follows: $O_2 > O_1 > O_3$. So, according to this model, the best decision is O_2.

Although WSM provides a great and simple approach to having multiple weighted criteria, it gives no guidance regarding how to rank them. It creates difficulties and confusion for users to rank the criteria. This issue also affects the reliability of the result since the determined weights highly depend on the person that uses the model. No minimum or maximum number can be given as a weight. Therefore, it is possible that one high-weighted factor can affect the final decision by itself (Marler et al., 2010).

2.2.6.2. Elimination et Choice Translating Reality (ELECTRE)

The ELECTRE model is a binary outranking model for multicriteria decision-making (Roy, 1991). This method assigns weights to each alternative and criteria to find their ranking. Then, the alternatives are compared to pre-defined thresholds. Decision-makers must have well-defined data to determine the thresholds (Taherdoost et al., 2023). This comparison aims to determine the alternatives' concordance and discordance based on each criterion. During the ELECTRE process, the alternatives that do not comply with the thresholds are eliminated. After the elimination, the remaining alternatives are compared with each other. The alternative with the highest ranking is considered the best alternative. In summary, the ELEKTRE method aims to establish alternatives that outrank other alternatives using thresholds and weights (Roy, 1991; Mary et al., 2016; Triantaphyllou, 2000).

The ELECTRE method is not suggested for decision-making processes with few alternatives because of the elimination approach (Taherdoost et al., 2023)

The decision-making can be completed by the following steps by using the ELECTRE model (Roy, 1991; Mary et al., 2016; Triantaphyllou, 2000; Taherdoost et al., 2023).

Step 1: Decide on m alternatives and n criteria, then normalise the matrix.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$$

Step 2: Weight the normalised matrix.

$$V = (v_{ij})\ n\ x\ m \text{ where } v_{ij} = w_j\, r_{ij}$$

Step 3 : Separate the criteria into concordance and discordance sets. The criteria is placed in the sets based on the decision maker's perception of the criteria's negativity or positivity.

$C_{kl} = \{j | v_{kj} \geq v_{ij}\}$

$D_{kl} = \{j | v_{kj} v_{ij}\} = j - C_{kl}$

Step 4: Build the concordance matrix by calculating the concordance index set.

$$C_{kl} = \sum_{j \epsilon C_{kl}} w_j$$

Then from the matrix as follows;

$$\text{C} = \begin{bmatrix} - & \cdots & c_{1m} \\ \vdots & \ddots & \vdots \\ c_{m1} & \cdots & c_{mn} \end{bmatrix}$$

Step 5: Build the discordance matrix by calculating the discordance index set.

$$d_{kl} = \frac{\max\limits_{j \epsilon D_{kl}} |V_{kj} - V_{ij}|}{\max\limits_{j \epsilon D_{kl}} |V_{kj} - V_{ij|}}$$

Then from the matrix as follows;

$$\text{D} = \begin{bmatrix} - & \cdots & d_{1m} \\ \vdots & \ddots & \vdots \\ d_{m1} & \cdots & d_{mn} \end{bmatrix}$$

Step 6: Determine the concordance dominance matrix (f).

First, the threshold for concordance ($\overline{c}$) should be calculated To determine the concordance dominance matrix.

$$\overline{c} = \sum_{\substack{k=1 \\ k \neq l}}^{m} \sum_{\substack{l=1 \\ l \neq k}}^{m} \frac{c_{kl}}{m(m-1)}$$

After calculating the ($\overline{c}$) value, matrix (f) can be created.

If $c_{kl} \geq \overline{c}$ then $f_{kl} = 1$.

If $c_{kl} < \overline{c}$ then $f_{kl} = 0$.

Step 7: Determine discordance dominance matrix (G).

First, the threshold for concordance ($\overline{d}$) should be calculated to determine the discordance dominance matrix.

$$\overline{d} = \sum_{\substack{k=1 \\ k \neq l}}^{m} \sum_{\substack{l=1 \\ l \neq k}}^{m} \frac{d_{kl}}{m(m-1)}$$

After calculating the ($\overline{d}$) value, matrix (G) can be created.

If $d_{kl} \leq \overline{c}$ then $G_{kl} = 1$.

If $d_{kl} > \overline{d}$ then $G_{kl} = 0$.

Step 8: Create the aggregate matrix (E) by multiplying the f and G matrices.

Step 9: Eliminate the less preferable alternatives in the matrix E. After the elimination, choose the alternative with the highest ranking.

2.2.6.3. Technique for Order of Preference (TOPSIS)

The main logic of TOPSIS is to calculate the distance between the alternatives and the ideal and worst (nadir) solution when deciding. The distance calculation is done by vector normalisation; the alternative with the shortest distance to the ideal solution and the greatest distance to the worst solution is considered the best option (Yoon et al., 1981; Chakraborty, 2021).

The TOPSIS model can be used by following the seven steps below (Liu, 2004; Sahoo et al., 2022):

Step 1: Decide on m alternatives with n criteria. Then normalise the vectors (Sahoo et al., 2022).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{ij}^2}}, \text{ i = 1,2,3,4, …….., } m; \text{ j = 1,2,3,4,……,} n.$$

Step 2: Decide on the importance weights W_k for each criterion. This weighting is not based on any scale; there is no upper or lower limit for weights similar to WSM (Liu, 2004; Sahoo et al., 2022).

$$t_{ij} = r_{ij}\, x\, w_j;\ i = 1, 2, \ldots., m \text{ and } j = 1, 2, \ldots., n.$$

$$w_j = \frac{w_j}{\sum_{k=1}^{n} w_k}, j = 1, 2, \ldots., n$$

$$\sum_{i=1}^{n} i = 1$$

w_j = indicator's original weight.

Step 3: Identify the ideal alternative, A^+.

Step 4: Identify the worst alternative, A^-.

Step 5: Calculate the distance between each criterion to the ideal (D^+) and worst (D^-) alternative with the Euclidean distance theory (Chakraborty, 2021).

$D^+ = \sqrt{\sum_{j=1}^{j}(v_{ij} - v_j^*)^2}$

$D^- = \sqrt{\sum_{j=1}^{j}(v_{ij} - v_j^-)^2}$

Step 6: Then calculate the ratio R of distance to the ideal alternative divided by the total of the ideal and worst distance. This ratio should be calculated for each criterion separately.

$$R = \frac{D^-}{D^- + D^+}$$

Since there is no guidance on weighting, it is highly subjective, and there is no upper/lower limit when weighing (Kochkina et al., 2017; Olson, 2004).

2.2.6.4. VIšekriterijumsko Kompromisno Rangiranje (VIKOR)

Similar to the TOPSIS method, VIKOR also calculates the distance of the ideal alternative to each criterion. In the VIKOR method, the criteria should be conflicting (Opricovic et al., 2004). To further explain the meaning of contradictory criteria, two or more criteria affect each other negatively (Opricovic et al., 2004). For example, Let us assume that there are two criteria available for the decision maker; C1 and C2. The ideal alternative occurs when C1 and C2 have the highest importance. However, these two criteria conflict with each other, and when the value of one is increased, the other criteria value is decreased.

In this model, the best decision is defined as the alternative that has the lowest distance to the best alternative (Huang et al., 2009).

The VIKOR method can be performed with the following steps (Siregar et al., 2018):

Step 1: Assign weights to each criterion and alternatives.

Step 2: Normalise the matrix

$$R_{ij} = \frac{(x * j - x_{ij})}{(x * j - x'j)}$$

Xij = Value of alternative i for criteria j

$i =$ alternatives

$j =$ criteria

x*j = Best value of a criterion

x'j = the worst value of a criterion

Step 3: Calculate the average deviation for each alternative (S).

$$S_i = \sum_{j=1}^{n} w_j \, x \, R_{ij}$$

w_j = weighting criteria

Step 4: Calculate the deviation range for each alternative (R).

$$R_i = \text{Max j } [w_j \, x \, R_{ij}]$$

Step 5: Calculate the VIKOR index.

$$\text{VIKOR Index} = \left[\frac{S_i - S'}{S* - S'}\right] \text{ x V} + \left[\frac{R_i - R'}{R* - R'}\right] \text{ x (1-V)}$$

S'= Smallest S value

S*= Largest S value

R'= Smallest R value

R*= Largest R value

The alternative with the smallest VIKOR index is considered the best alternative (Huang et al., 2009; Siregar et al., 2018).

VIKOR method is primarily used in situations where the decision maker is not able to determine its preferences due to conflicting criteria. This model calculates the best decision by a compromised solution that aims to minimise the regret and maximise the major utility (Opricovic et al., 2004).

The difference between TOPSIS and VIKOR is VIKOR method does not calculate the distance between the worst alternative to each criterion. Therefore, the focus of VIKOR is only the ideal alternative for decision-making (Huang et al., 2009). Also, in the TOPSIS method, the criteria are not necessarily conflicting (Opricovic et al., 2004)

2.2.6.5. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process is a widely used multicriteria decision-making model by Thomas Saaty due to its structure and ease of use (Liu et al., 2020). In the AHP Model, the decision-making is done by following a hierarchical structure, pairwise comparison, allocating weights to each criterion and alternative and finally selecting an alternative that is considered to be the best (Adamczak et al., 2016; Chan et al., 2008; Franek et al., 2014). The top level of the hierarchy represents the main objective of the decision. Then, this top level is broken down into the researcher's decision-making criteria. At the bottom level, alternative decision options are placed (Saaty,1990).

The model is explained in the following four steps:

Step 1: Structure the objective, criteria and alternatives and create an AHP structure as shown in Figure 4 (Saaty,1990).

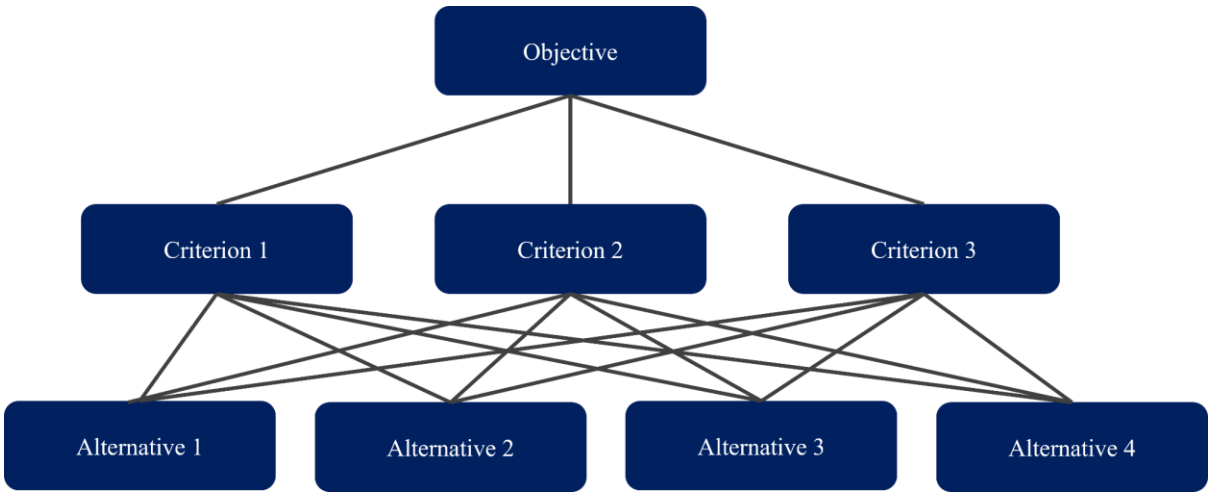

Figure 4: AHP Structure (Saaty,1990)

Step 2: Compare all the criteria and alternatives pairwise to determine their weights according to their importance using the AHP scale (Saaty,1990). The AHP scale consists of numbers from one to nine,

each indicating a different importance level, as shown in Table 3. After the weights are given, the priority vector must be calculated to determine the overall importance of the criteria and alternatives. The priority vector is the principal eigenvector of the matrix (Saaty,1990).

Table 3: AHP scale range (Saaty,1990)

AHP Scale	Meaning
1	Equal importance
3	Moderate importance of one over another
5	The essential or vital importance
7	Very vital importance
9	Extreme importance
2,4,6,8	Intermediate values between two levels

So, according to the given structure, the pairwise comparison and weighting according to the AHP scale should look like below.

	Criterion 1	Criterion 2	Criterion 3	Priority Vector
Criterion 1	1	5	3	0,63334572
Criterion 2	1/5	1	1/3	0,106156324
Criterion 3	1/3	3	1	0,260497956

Final Priorities= C1> C2 > C3

Criterion 1	Alternative 1	Alternative 2	Alternative 3	Priority Vector
Alternative 1	1	1/3	1/5	0,106156324
Alternative 2	3	1	1/3	0,260497956
Alternative 3	5	3	1	0,63334572

Final Priorities for Criterion 1= A3 > A2>A1

Criterion 2	Alternative 1	Alternative 2	Alternative 3	Priority Vector
Alternative 1	1,00	6,00	0,14	0,326761
Alternative 2	0,17	1,00	9,00	0,349452
Alternative 3	7,00	0,11	1,00	0,323786

Final Priorities for Criterion 2= A2 > A1>A3

Criterion 3	Alternative 1	Alternative 2	Alternative 3	Priority Vector
Alternative 1	1,00	3,00	4,00	0,549008
Alternative 2	0,33	1,00	9,00	0,365542
Alternative 3	0,25	0,11	1,00	0,08545

Final Priorities for Criterion 3= A1 > A2>A3

Step 2.1: If this is group decision-making, the participants should weigh the criteria and alternatives separately. After the weighting part, their weights should be aggregated by taking the geometric mean of the weights (Saaty,1990).

Step 3: Calculate the consistency ratio of pairwise comparisons to make sure the weighting is not inconsistent (Saaty,1990).

Inconsistency means there are contradictions in the weighting process during pairwise comparisons. It occurs when the relative importance assigned to criteria or alternatives is inconsistent.

The consistency index (CI) can be calculated as follows (Saaty,1990; Franek et al., 2014):

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

n = Number of rows in the matrix

λ_{max} = The highest eigenvalue of the matrix

$$\lambda_{max} = \sum_{j=1}^{n} \frac{(S.v)_j}{n.v_j}$$

S= Pair-wise comparison matrix

If the consistency index (CI)= 0, then the weighting is considered to be perfectly consistent.

However, the number of pair-wise comparisons has a linear relation with the possibility of inconsistency. In those situations, the consistency ratio should be calculated (Franek et al., 2014).

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

RI = Random Index

In CR calculation, the RI should be selected carefully based on the number of rows. The RI numbers are pre-calculated and determined by constant values (Saaty,1990). The RI value for a corresponding number of rows can be examined in Table 4.

Table 4: RI values (Saaty,1990).

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1.48	1,56	1,57	1,59

If the consistency ratio > 0.1, then the weighting is inconsistent and should be calculated again (Franek et al., 2014).

Step 4: The final step calculates the final general prioritisation of alternatives by multiplying the final priority vector of alternatives by each criterion and then summing alternative values (Saaty,1990). According to this step, the alternative with the highest prioritisation total should be selected.

	Alternative 1	Alternative 2	Alternative 3	Criteria Weights
Option 1	0,106156324	0,260497956	0,63334572	0,63334572
Option 2	0,326761162	0,349452369	0,323786469	0,106156324
Option 3	0,549007654	0,365542234	0,085450112	0,260497956

	Alternative 1	Alternative 2	Alternative 3
Option 1	0,067233653	0,164985266	0,401126801
Option 2	0,034687764	0,037096579	0,034371981
Option 3	0,143015372	0,095223005	0,022259579
Total Alternative Value	0,244936789	0,297304849	0,457758362

According to the AHP model results, selecting Alternative A3 has the maximum benefit and should be chosen.

Compared to the WSM model, calculating AHP is more complex and requires more time. However, it guides how to rank the weights and puts an upper and lower limit for ranking them by providing a scale (Kochkina et al., 2017). Therefore, there cannot be extreme gaps between the criteria weights (Adamczak et al., 2016). Saaty claims that the scaling approach and guidelines minimise the subjectivity of giving weights to the criteria and make it possible to compare the criteria objectively (Saaty, 1990).

2.2.6.5.1. Fuzzy AHP (FAHP)

Fuzzy AHP is an extension to regular AHP for situations when there is uncertainty and vagueness in the criteria, and the decision-makers are not able to assign exact numbers as weights (Özdağoğlu et al., 2017; Chan et al., 2008; Xu et al., 2014). Similar to classical AHP, Fuzzy AHP also has the same hierarchical structure, pairwise comparison and consistency checking (Chan et al., 2008; Franek et al., 2014). Unlike the classical AHP, the most significant difference is that Fuzzy AHP does not provide the 1-9 scale because it assumes that these crisp values do not represent the criteria with ambiguity (Özdağoğlu et al., 2017; Chan et al., 2008). Instead of using the 1-9 scale, fuzzy AHP converts linguistic terms such as identical, a little more important, a little less important and much less important to triangular fuzzy numbers (Liou et al., 1992; Chan et al., 2008; Xian et al., 2013). The fuzzy AHP scale can be examined in Table 5.

Table 5: Fuzzy AHP Ranking

Linguistic variable	Fuzzy number	Fuzzy number scale
Identical	1	(1, 1, 1)
More important	6	(5, 6, 7)
Much more Important	9	(8, 9, 10)
A little less important	1/3	(1/2, 1/3, 1/4)
Less important	1/6	(1/5, 1/6, 1/7)
Much less important	1/9	(1/8, 1/9, 1/10)

Fuzzy AHP can be explained by the following steps after creating the structure same as the classic AHP (Liou et al., 1992; Liu et al., 2020):

Step 1: Pairwise comparison of criteria and alternatives

Step 2: Multiple judgement aggregation.

Very similar to the classical AHP, if there is group decision-making, every decision-maker can have different weights. In this step, these different weights are aggregated.

Step 3: Fuzzy weights defuzzification and final comparison.

In this step, the fuzzy numbers are converted to crisp numbers. This is an extra step compared to classical AHP because it is challenging to compare fuzzy numbers compared to crisp numbers.

Step 4: Consistency measurement.

To prevent conflicts in the ranking, a consistency check is a must to ensure that the pairwise comparisons are consistent.

Although this model is highly similar to the differences between them AHP, there is criticism towards its differences as follows:

- This model is generally criticised for its inability to address the uncertainty of the criteria and situations where the decision-makers' perspective is needed (Chan et al., 2008).
- According to the creator of the classical AHP Saaty, the classical model is fuzzy enough to deal with uncertainties due to the fundamental AHP scale that includes linguistic variables (Saaty et al.,2007). Saaty et al. also suggests that making the AHP fuzzier creates validity issues because the fuzzy number might be significantly different from the actual number when it comes to the pairwise comparison (2007). Therefore, for AHP, using fuzzy numbers only increases the complexity of the decision-making (Saaty et al., 2007).

- The efficiency of FAHP compared to AHP is debatable (Tran, 2009; Chung et al., 2019).
- Fuzzy AHP is very complex compared to the classic AHP. The results are not worth the complexity (Raharjo et al.,2008)

2.2.7. Differences Between the Multi-Criteria Decision-Making Models

The differences in weighting and calculation methods of the MCDM models are explained in Table 6 below.

Table 6: Differences between the MCDM Models

	WSM	ELEKTRE	TOPSIS	VIKOR	AHP	FAHP
Criteria Weights	Assigned Weights, No weighting scale	It does not explicitly assign weights	Assigned Weights	Equal Weights, Conflicting Criteria	Determined by pairwise comparison, 1-9 Weight Scale	Determined by pairwise comparison, Fuzzy Weights
Calculation Approach	Weighted Sum	Outranking approach	Closeness to the ideal and nadir alternative	Closeness to the ideal solution	Pairwise Comparison	Pairwise Comparison

2.3. Factors that Affect (De) Centralisation Decision

Based on the reviewed literature, seven main factors are determined to be considered while making (de)centralisation decisions. These factors should be considered because the decision influences these factors. If an enterprise aims to benefit from these factors, then the decision should be made by considering the decision's effect on them.

2.3.1. Innovativeness

Innovativeness means the ability to develop and deliver new products, services, processes, and business models for customers (Ilori et al., 1997). According to Nell et al., enterprises should use various software applications. Because using a single tool can limit the innovativeness of the company. Although the tools might be similar according to their field of use, they still provide different features, and it is beneficial for a company to use those different features. Variety is a must

for innovation because single software means it limits creativity with its features. It is impossible even if the user wants to do more (2021).

Daoping et al. also found similar results after analysing the number of patents of 89 companies in China. Software application centralisation causes challenges when it comes to performing different tasks. More than a single tool is needed to complete various activities. Therefore this leads to a limitation on the innovativeness of the company. If the enterprise acquires a variation of software applications, then it can achieve innovation capability (Daoping et al., 2016).

By using the same logic, Blind and Thumm have also analysed the number of patents by using data from 149 different European companies. Similarly, they found a negative relationship between centralisation and the company's innovativeness (Blind et al., 2017).

2.3.2. IT Cost

According to Schuff et al., centralised software applications reduce IT costs by 50% (2001). Ahlemann et al. also concluded similar results that centralised software applications reduce IT costs by 33% (2022). The reason is that decentralisation leads to diverse technologies in a company. All of these different technologies require different types of usage and instructions. Since there are various applications, different licences and more employees are needed to support these applications. These decentralisation factors create difficulties in managing those technologies and increase costs (Ahlemann et al., 2022; Magnusson, 2013). However, with centralisation, companies can benefit from the Economies of Scale (EoS) by purchasing the same amount of licenses from the same supplier (Akkermans et al., 2022; Ahlemann et al., 2022).

2.3.3. Flexibility

Although centralised software applications provide more control than decentralised ones, are easy to maintain, cost-efficient, and easily supported by the IT department, it is not flexible. This creates a risk because the environment of the enterprise can be unpredictable and changes rapidly. To be able to keep up with environmental changes, various software applications are needed. Standardisation of the tool limits the ability to react to the changes. New changes require new solutions. It is a challenge to add new technologies to a company after the centralisation of software applications (Magnusson, 2013). Magnusson recommends implementing decentralisation locally instead of company-wide decentralisation to address this issue (2013).

Ahlemann et al. oppose Magnusson regarding the influence of decentralisation on flexibility (2022). They claim centralised software applications provide more flexibility since it removes the effort of introducing and getting used to a new tool. However, the researchers also indicate that this result only

occurs if the standardised software applications are adaptable to the changing market (Ahlemann et al., 2022).

2.3.4. IT Support

IT support is the ability of an enterprise to provide support to its employees for the used software. With centralisation, the IT department has more control over the software tools because the number of tools is lower than decentralisation. Therefore, IT departments can provide IT support much quicker for centralised software applications (Magnusson, 2013). With decentralisation, the IT support Ability of the company will be much lower than centralisation. Because more software applications require more knowledge, which is time-consuming and costly to acquire (Parsons et al., 2014; Magnusson, 2013)

Additionally to these, more need for IT support increases the IT cost. To provide more extensive IT support, enterprises need to hire more employees and should be able to provide training for more software applications. Therefore, centralising software applications also decreases the IT cost because it limits the cost created by IT support (Magnusson, 2013).

2.3.5. Integration Ability

Integration ability is integrating the tools or solutions with different software units in the company (Sklyar et al., 2019; Akkermans et al., 2002). Centralisation of software makes integration between the units and the partners easier. The reason is: Centralization provides more control over the different software applications (Sklyar et al., 2019). It is easy to add partners and teams to the network since there will be one software application instead of trying to manage the integration of all the possible variables (Akkermans et al., 2002).

2.3.6. Collaboration Ability

Collaboration ability is the ability of the employees to work together. The decentralisation of software applications hinders employee collaboration (Akkermans et al., 2002). It is not very likely for the different software applications to provide an option to work together. So, in a software application decentralised company, the collaboration of the employees or teams decreases. The level of collaboration ability decreases when decentralisation increases (Sklyar et al., 2019).

2.3.7. Task Completion Speed

Task completion speed is the amount of time to complete a particular task. As a result of surveys with many software development managers, Zmud concludes that a lack of available software features leads to slowing the employees down due to software application centralisation (1982). According to

Zmud (1982), using multiple tools for a task can increase the completion speed because more tools can provide more features to help complete specific tasks faster.

However, Parsons et al. (2014) disagree. According to their findings, the IT department's low ability to support the tech tool due to decentralisation wastes time. The IT team needs to gather information about the various software tools while the users wait for them instead of working with the tool (Parsons et al., 2014).

2.4. Literature Review Summary

In this section, the summary of the findings from the literature review is presented. First, the summary of each decision-making model is explained. Then, a research framework is created with the factors that affect software application (de)centralisation decisions, followed by a citation table of this framework.

2.4.1. Summary of Decision-Making Models

In the literature review of this study, nine decision-making models are considered. The summaries of the considered decision-making models are presented in Table 7.

Table 7: Decision-Making Models Summary

Name of the Model & Citations	Main Features
SAFe Take versus Delegate Thinking Framework (Oren, 2023)	A decision-making model specialised for (de)centralisation decisions. Calculates a total value by summing the involved criteria and guiding the user to choose (de)centralisation, according to the final calculation
Cost Benefit Analysis (Robinson, 1993)	A decision-making tool that quantifies the costs and benefits of the alternatives.
The Four Forces of Marketing Operations (Brinker, 2018)	A model that makes suggestions for when to (decentralise). It only considered the EoS and Speed as the decision-making criteria.
WSM (Triantaphyllou, 2000), (Marler et al., 2010)	Multiplying the option values and criteria weights, then sum all the values for each option. The option with the highest value is considered the best option.
TOPSIS (Yoon et al., 1981), (Subrate, 2021), (Chakraborty, 2021), (Liu, 2004), (Sahoo et al., 2022), (Kochkina et al., 2017), (Olson, 2004)	Chooses the alternative with the shortest distance to the ideal option and the greatest distance to the worst (nadir) option.
ELEKTRE (Mary et al., 2016), (Roy, 1991), (Triantaphyllou, 2000)	Outranks the alternative by assigning weights and thresholds to criteria
VIKOR (Opricovic et al., 2004), (Siregar et al., 2018) (Huang et al., 2009)	Chooses the alternative that has the shortest distance to the ideal option
AHP (Saaty,1990) (Adamczak et al., 2016) (Kochkina et al., 2017) (Chan et al., 2008)	Breaks down the decisions into a hierarchy of smaller units. Then a pairwise comparison is used to determine the importance of the criteria based on the crisp 1-9 scale given.
FUZZY AHP (Özdağoğlu et al., 2017), (Chan et al., 2008), (Xu et al., 2014), (Liou et al., 1992), (Xian et al., 2013), (Liu et al., 2020), (Saaty et al., 2007), (Tran, 2009), (Chung et al., 2019), (Raharjo et al.,2008)	Breaks down the decisions into a hierarchy of smaller units. Then a pairwise comparison is used to determine the importance of the criteria based on the fuzzy numbers and linguistics.

2.4.2. Research Framework

Based on the previous studies presented in Table 8, the factors that need to be considered for (de)centralisation decision are determined. Based on these factors, we created a framework to guide the research. The visualisation of the framework based on the reviewed factors is shown in Figure 5.

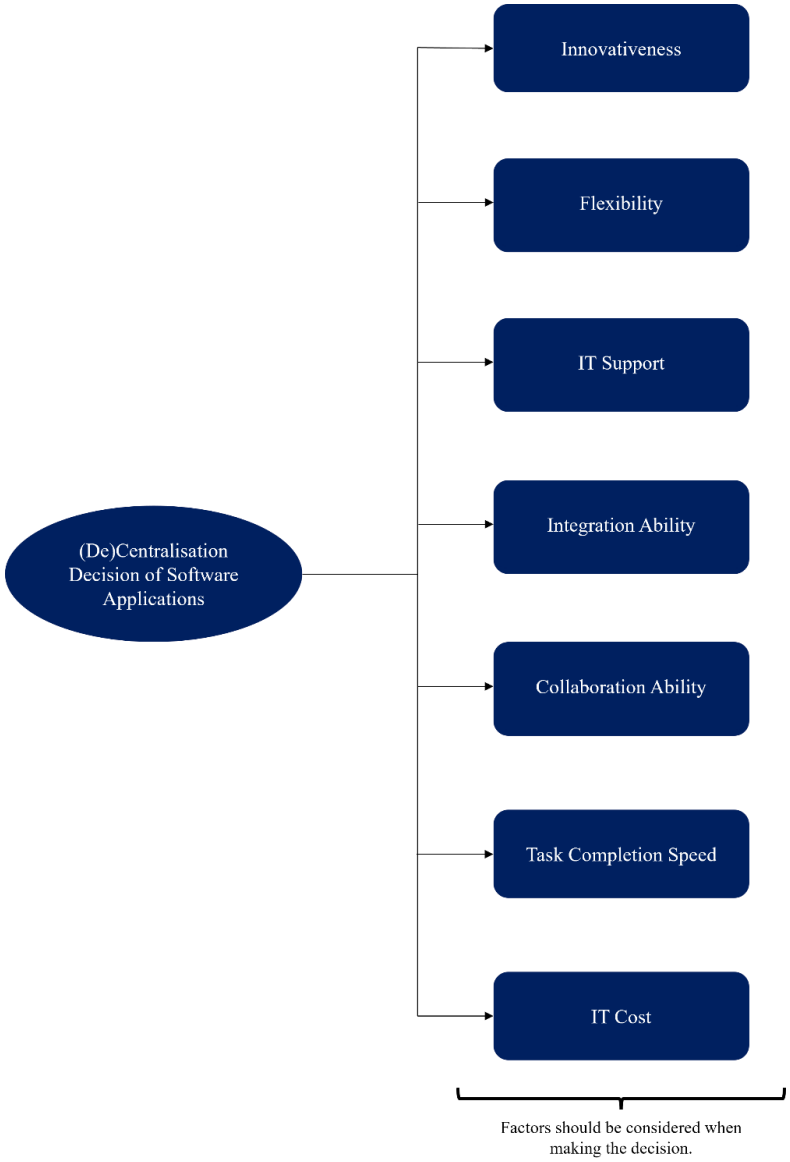

Figure 5: Research Framework Based on the Reviewed Literature

2.4.3. Sources of Framework Creation

We created Table 8 below to show the citations for the research framework created by the reviewed factors for the decision-making.

Table 8: Research Framework Citations

Reviewed Literature	Factors That Should be Considered for Software Application (De)Centralisation Decision						
	Innovativeness	**Flexibility**	**IT Support**	**Integration Ability**	**Collaboration Ability**	**Task Completion Speed**	**IT Cost**
Akkermans et al., 2002	X		X	X	X		X
(Magnusson, 2013)	X	X	X				X
(Ahlemann et al., 2022)		X	X				X
(Paik et al., 2017)	X			X			X
(Parsons et al., 2014)			X			X	
(Sklyar et al., 2019)			X	X	X		
(Schuff, et al., 2001)			X				X
(Zmud, 1982)	X					X	
(Kim et al., 2017)				X			X
(Daoping et al., 2016)	X	X					
(Acemoglu, et al. 2007)			X				
(Nell et al., 2021)	X						
(Ilori et al., 1997)	X						

3. Methodology

This Section will discuss the methodologies used to perform this research. In this research, a mixed research methodology is used. This research will use design science and case study methodologies to answer the research question and develop a decision-making model.

3.1. Research Design

The research method used in this research is qualitative. The qualitative data are gathered from the workshops and the questionnaire.

In qualitative research, the case study method is one of the most efficient methods if the researcher focuses on a specific situation, period or organisation (Bell et al., 2021). Therefore, the case study approach is selected to observe the success of the main deliverable of this research: a multi-criteria decision-making model. Since the research problem is highly related to the industry and requires data from a multinational organisation, this study was conducted as company research.

3.1.1. Design Science

The design science approach is selected because the main goal of the research is creating a decision-making model. According to Peffers et al. (2007), the design science approach has six steps, as shown in Figure 6.

(I) **Identify Problem & Motive:** The problem of this research is the challenge of deciding whether to centralise and decentralise software applications used in a company, as explained in detail in the Introduction . The aim and motive of this study are to provide a multi-criteria decision-making model to guide companies in the decision-making process.

(II) **Define the Objective of a Solution:** The solution's objective must be determined after the definition is clear. The proposed solution for this research is a multi-criteria decision-making model. The objective of developing this model is to make companies more confident and faster decisions. As mentioned in the Introduction, The objective of the decision-making model only aims to cover deciding on centralising or decentralising software applications being used in a company.

(III) **Artefact:** The multi-criteria decision-making model is the artefact in this research. Since the MCDM model of this study was created based on the literature review, the model can be examined in the Decision-Making Model Development part of this study.

(IV) **Demonstration:** This artefact should be used to make a decision. To simulate this decision process, workshops are conducted, and the participants are asked to use the decision-making model.

(V) **Evaluation**: After using the decision-making model and sharing the results with the participants, the model's efficiency is observed through feedback.

(VI) **Communication**: The research will be published (Peffers et al.,2007).

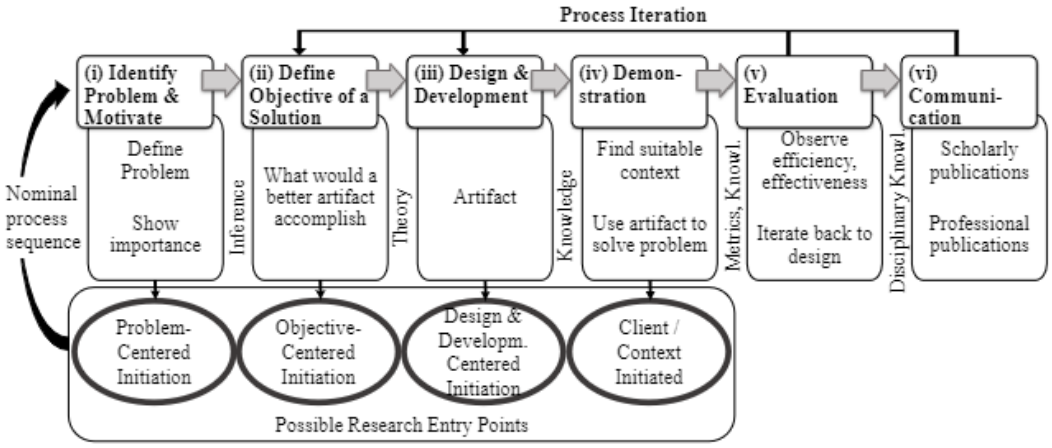

Figure 6: Design Science Framework (Peffers et al.,2007)

Please see the table below to summarise the equivalent of the design science process to this study.

Table 9: Design Science Step Equations of The Study

Design Science Steps	The Equivalent in this Study
(I) Identify the Problem & Motive	Difficulty in deciding whether to centralise or decentralise the SW tools used in a company.
(II) Define the Objective of a solution	To develop an MCDM model (AHP).
(III) Artefact	MCDM model to decide whether to centralise or decentralise the SW tools used in a company.
(IV) Demonstration:	Conducting workshops.
(V) Evaluation:	Evaluating questionnaire results after the workshop regarding the model.
(VI) Communication	Publishing the results.

3.2. Case Study

This research is a company project at Kraft Heinz Company (KHC). To be more specific, the research will be conducted within the IT department.

Kraft Heinz is one of the world's largest food and beverage companies with over 200 brands, 38000 employees and operates in more than 40 countries (Kraft Heinz, 2023). KHC uses different analytics tools to analyse its data in the company. The company aims to centralise these tools to facilitate the management of these tools and exploit cost reduction. However, due to different needs, the company is experiencing challenges regarding the centralisation of analytics technologies. Since KHC is a large multinational company, local needs and employee backgrounds and skills differ. Therefore the selection of tools varies according to the characteristics of the teams and the regions. As a result, deciding whether to centralise or decentralise software applications is a challenge for the company.

The study was conducted separately for Asia, Australia, Europe, Latin, and North America. Therefore, each region is handled as a different case.

3.3. Data Collection

The aimed outcome of data collection for this research is to collect feedback from the company employees regarding the usefulness of the developed decision-making model by conducting workshops. Questionnaires are filled out among the selected KHC employees to collect the data.

The questionnaire is selected as the data collection method because the aim is to get the participant's feedback as soon as possible without needing another meeting later so that the workshop participants can remember the model's details.

3.4. Workshop Design

The workshops consist of three parts. As shown in Figure 7, in the first part, the problem, aim of the study, developed model and the usage of the model are explained. Then, in the second part, participants will be asked to use the multi-criteria decision-making model, and then the model result will be shared with them. Lastly, participants will be asked to answer a questionnaire regarding the model's success in the third part of the workshop.

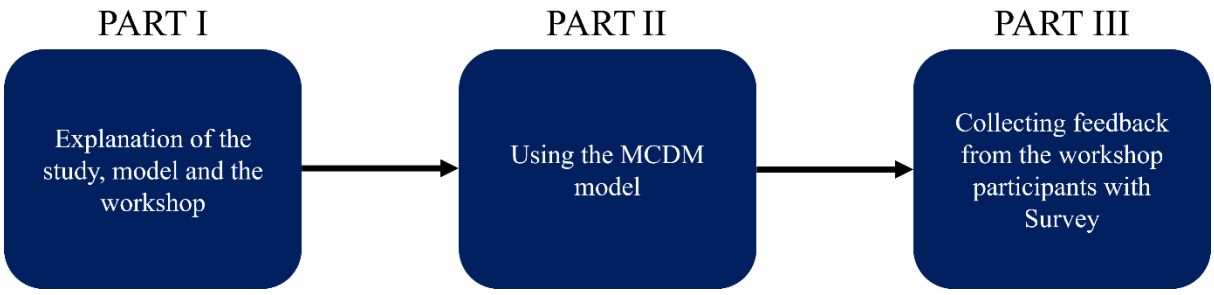

Figure 7:Workshop Structure

The workshops are designed for 2-3 participants and take 30 minutes. The reason for selecting a small group is related to the limited availability of the participants. Since all the workshop participants are from the senior management, they have simultaneous time and availability. Therefore, workshops were designed for 30 mins, and since conducting a workshop with more participants would take more time, the participant number in a group was kept small.

3.5. Workshop Participant Selection

To select the correct decision-making tool users and questionnaire participants, the following criteria were determined:

1. The interviewee should be working in the company for at least six months.
2. The interviewee should be in a position that is responsible for software application selection decisions.

The participants of the workshops are selected according to these criteria.

3.6. Questionnaire Design

The questionnaire is conducted to gather feedback from the workshop participants regarding the success of the tool. Unipolar Likert Scale is selected for scaling this questionnaire. Unlike bipolar scales, unipolar scales do not include a neutral option. Therefore, unipolar scales aim to prevent questionnaire participants' hesitation to choose a negative option and provide higher reliability (DeCastellarnau, 2017). To increase the reliability, the unipolar Likert Scale is selected.

The questionnaire consists of 15 questions, three parts and takes approximately 5-7 mins to finish.

a) **Part 1:** In this part, the questionnaire aims to measure the overall satisfaction of the model testers with multiple-choice questions. The questions are about the satisfaction of the model, the model's results, the relevance of criteria and the user interface. The options are as follows:

i. Not at all satisfied
ii. Slightly satisfied
iii. Moderately satisfied
iv. Very satisfied
v. Extremely satisfied

b) Part 2: In this part, the questionnaire aims to measure more specific factors such as confidence, comfortableness and speed of the model with multiple choice questions. These questions are designed as agree and disagree questions so the questionnaire participant can rapidly select the relevant option. The options are as follows:
    i. Not at all agree
    ii. Slightly agree
    iii. Moderately agree
    iv. Agree
    v. Extremely Agree
c) Part 3: In this part, the questionnaire aims to collect any additional feedback or remarks with an open-ended question.

The complete list of questionnaire questions is included in Appendix A.

4. Decision-Making Model Design

First, this research aimed to find a decision-making model specific to deciding whether to centralise or decentralise the software applications in a multinational company. However, after an extensive literature review, a specific model developed especially for this decision is not found. Therefore, as explained in the Introduction, the study aims to create a decision-making model, especially for this research, by modifying the existing general decision-making models. To select the base decision model used in this research, the following criteria are determined:

1. The decision-making model should support multiple criteria because many factors affect the (de)centralisation of software application decisions.
2. The criteria considered while deciding should be weighed since not every factor influences the decisions equally.
3. The model should have guidance on how to weigh the criteria for the subjectivity of the study.

4.1. Base Decision-Making Model Selection

After considering many different decision-making models, AHP is selected as this study's base decision-making model. The considered decision-making models and the reasons why they were not selected are explained in Table 10 below.

Table 10: Considered Decision-Making Models

Name of the Model	Used in This Research?	Reason
SAFe Take versus Delegate Thinking Framework	NO	Multi-criteria decision-making. No weighting; all factors affect equally. Criteria are insufficient for this study.
Cost Benefit Analysis	NO	There is no guidance for various costs and benefits that can be quantified and converted to financial value.
The Four Forces of Marketing Operations	NO	No weighting; all factors affect equally. The criteria and involved factors are too narrow for this study.
WSM	NO	Too basic. No guidance for weighing. Highly subjective.

ELEKTRE	NO	The outranking approach is not suitable for this study, No guidance for weighting, Determining thresholds is not convenient for this study due to the few alternatives.
TOPSIS	NO	No guidance for weighing. Highly subjective.
VIKOR	NO	The study's criteria are not necessarily conflicting, and VIKOR provides conflicting criteria comparison. There is no guidance, upper or lower limit for weighing.
FUZZY AHP	NO	More Complex than regular AHP, and there are suggestions that the results are not better than the regular AHP. Regular AHP already provides a number scale with corresponding linguistic terms.

The reasons why AHP is selected as the base model are: (1) It is a multi-criteria decision-making model, (2) it supports weighting the criteria; therefore, not all the criteria have the same importance, (3) It provides a weighing scale that aims to minimise subjectivity.

4.2. Criteria Selection

The criteria that are used in our AHP model are determined by the extensive literature review. The determined criteria are;

(1) Innovativeness
(2) Flexibility
(3) IT Support
(4) Integration Ability
(5) Collaboration Ability
(6) Task Completion Speed
(7) IT Cost

The details and the summary of the criteria can be found in the Literature Review Summary part of the paper.

4.3. Developing the AHP Structure

To design the model, AHP is used since it is the selected base model for the study.

The AHP hierarchy is created based on the study's objective, criteria and alternatives. The objective is to select (de)centralising the software usage located at the top level. After the top level, the seven criteria selected based on the literature review are placed in the middle level. Alternatives,

centralisation, decentralisation and hybrid usage are placed at the base level. By placing the criteria and alternatives into the base MCDM model: AHP, the decision-making model creation for this study is finalised.

This study's AHP structure visualisation is shown in Figure 8.

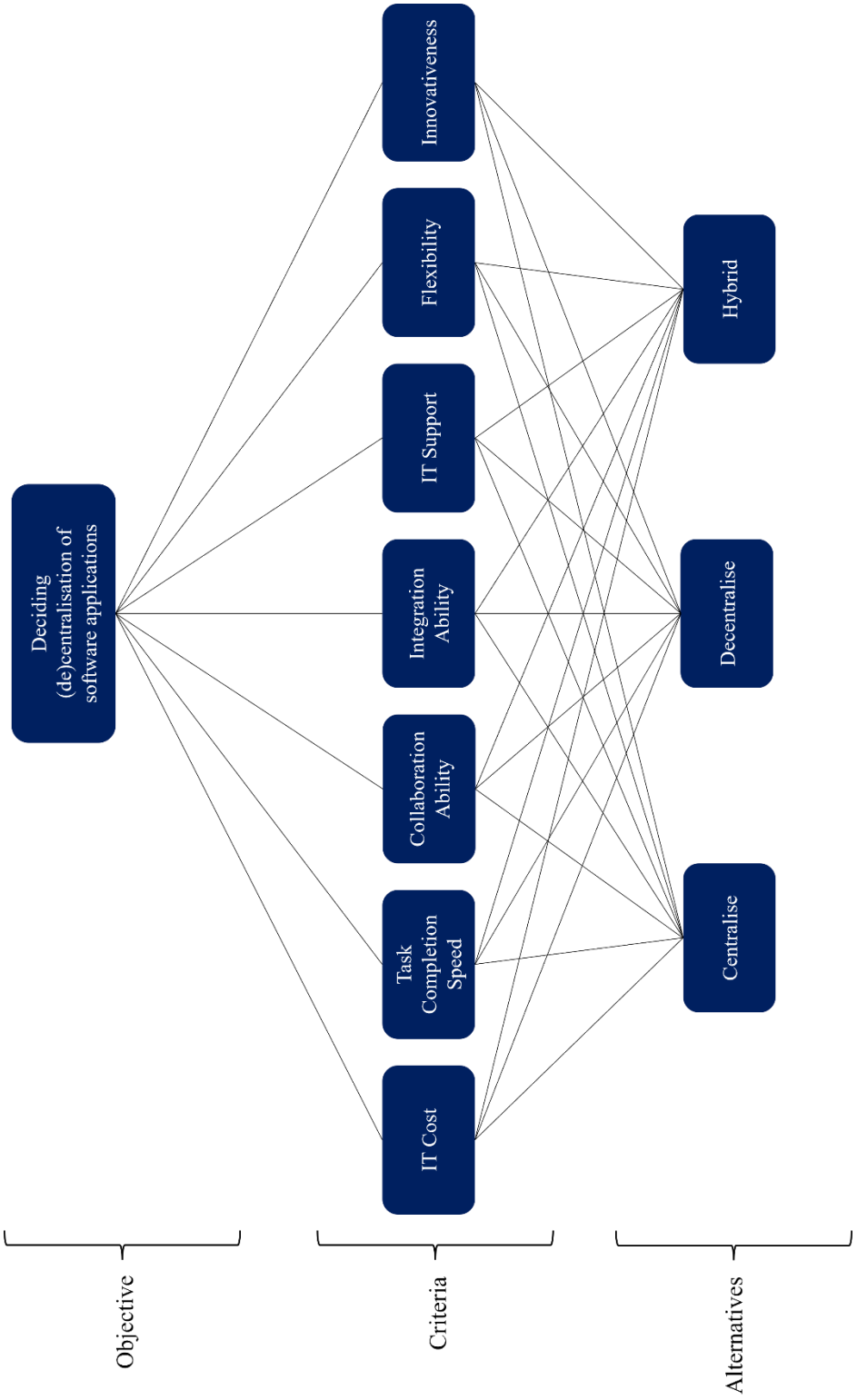

Figure 8: AHP Structure of the Study

4.4. Model Implementation

After selecting the criteria and a base decision-making model, the model needed to be modified and visualised for workshop participants' usage. Model visualisation is done with the Miro[1] platform, while the AHP calculations are performed with Microsoft Excel. Miro is a virtual workspace allowing users to work collaboratively in real-time. For AHP calculations, the steps and formulas explained in the Literature Review are used.

The developed model consists of three steps that participants need to complete to make the decision. The three steps are explained as follows:

Step 1: The participants must select four of the seven initial criteria. Participants chose those four criteria by the voting feature of Miro. The first four criteria with the most votes are selected for the study's next steps. The workshops are designed for four criteria because of the time restrictions. Since the participants needed to repeat Step 3 for the number of criteria times, the criteria needed to be reduced to save time. A sample visualisation of Step 1 is provided in Figure 9. The most voted criteria shown in Figure 9 are only the sample criteria for understandability. The criteria in this figure are not obtained from the conducted workshops. The actual workshop Miro frames can be examined in Appendix B.

[1] https://miro.com

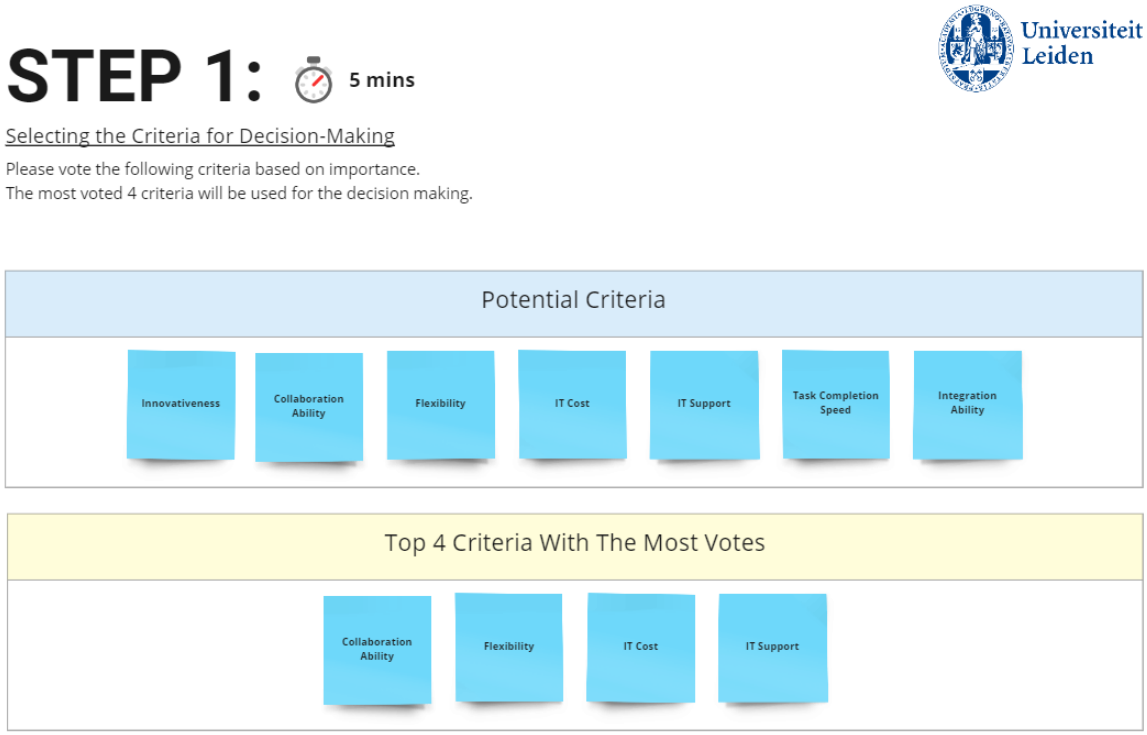

Figure 9: Workshop Step 1 Visualisation

Step 2: In this step, every participant compares the importance of selected criteria with each other and ranks these criteria according to the AHP scale. At the end of this step, participants will be able to address the most and least important criteria for their decision. The visualisation of Step 2 is shown in Figure 10 below.

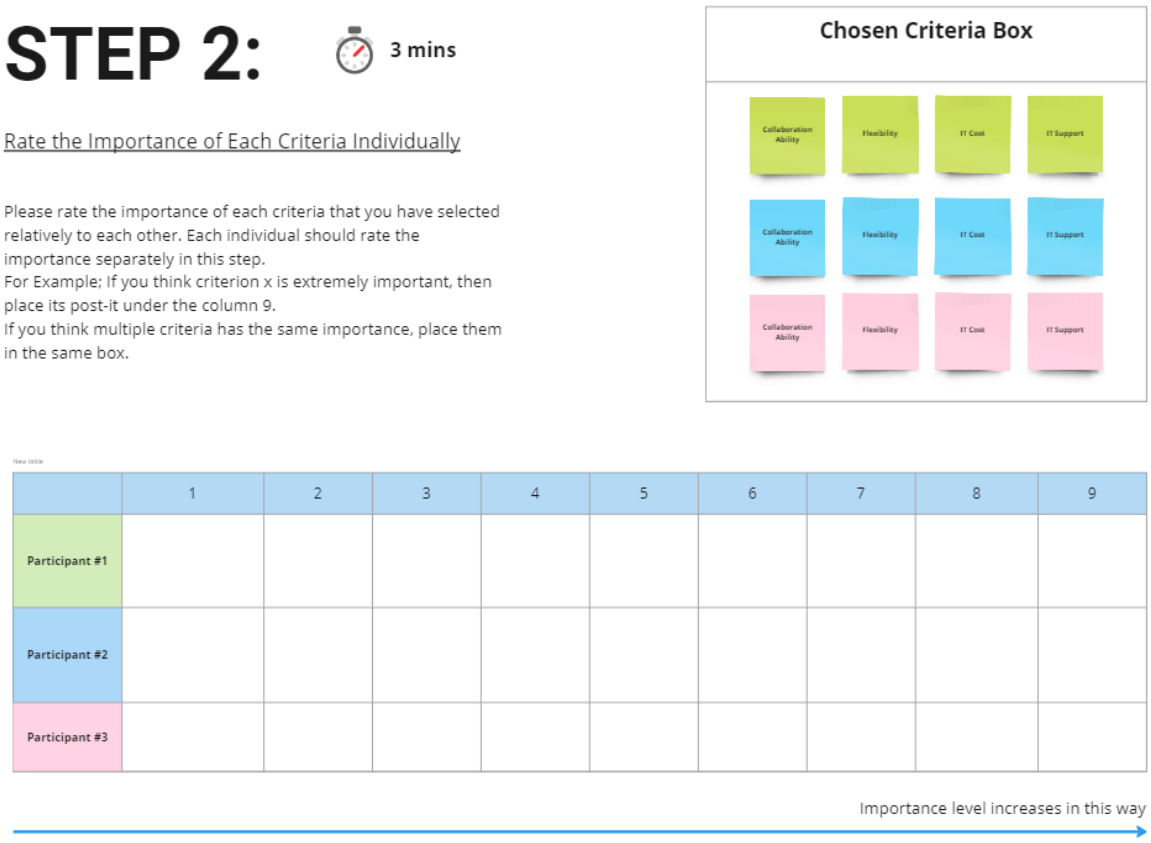

Figure 10: Workshop Step 2 Visualisation

Step 3: In this step, every participant compares the preferability of alternatives with each other based on the selected criteria. Then the participants rank these criteria according to the AHP scale. This step must be repeated for each criterion selected since the comparisons depend on the criteria. At the end of this step, participants will be able to address the most and least preferable alternatives for their decision. The visualisation of Step 3 is shown in Figure 11 below.

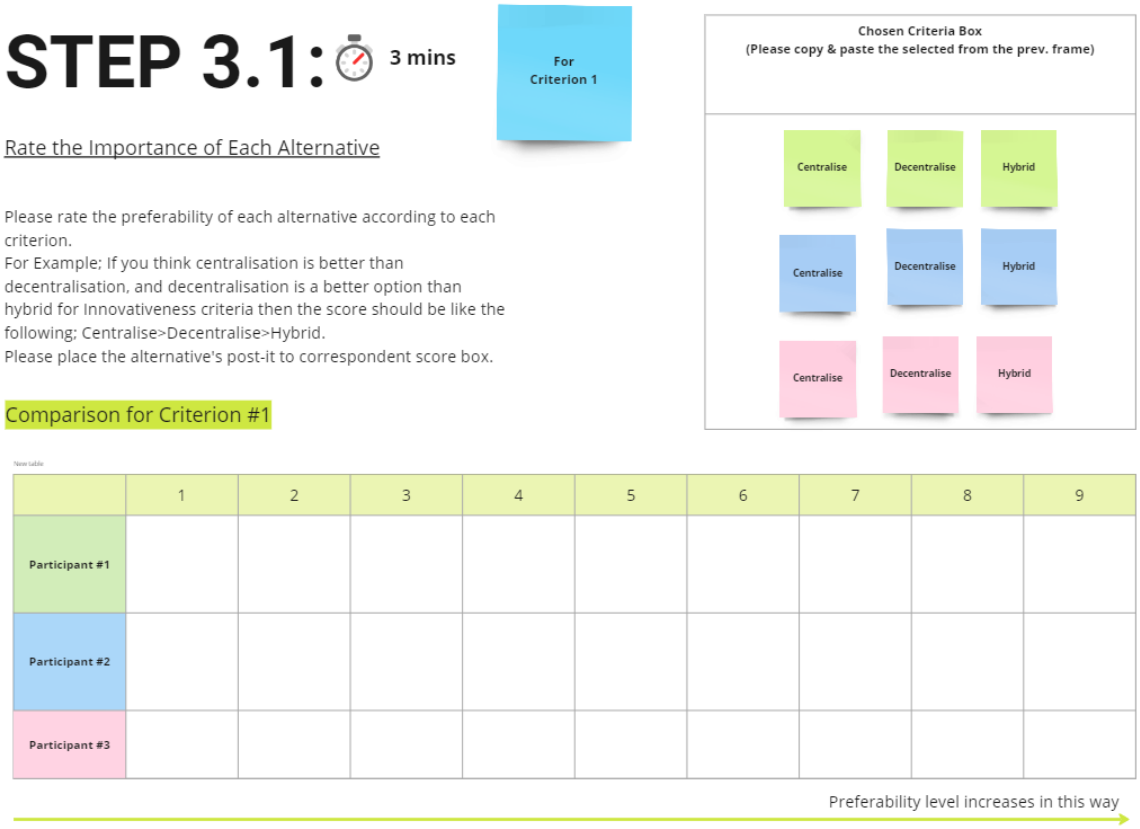

Figure 11: Workshop Step 3 Visualisations

Miro's timer feature is used to not go beyond the given time. This way, participants could see their remaining time for each step.

The results are calculated according to the ranking of the participants with the AHP algorithm by Excel. This Excel file is designed to be shared with the participants as an outcome of the workshop.

5. Results of the Study

In this part, the results of the study are explained by the data from the workshops and questionnaires. Every workshop will be examined as a separate case since they belong to different regions of the KHC.

The results are explained in two parts: (I) First, a cross-case analysis is performed and presented. (II) Second, results from every case are explained separately.

5.1. Cross-Case Analysis

In this part, all the cases are analysed together to present an overall analysis. First, the participant profiles are shown, and then a comprehensive look at the workshop and questionnaire results are provided.

5.1.1. Workshop Participant Profile

The workshop participants are selected based on the criteria explained in the Workshop Participant Selection part. Participants' workshop group, position in the company, number of years in the company, and their responsibility status to make the (de)centralisation decision of software application purchase are shown in the table below. For this study, four workshops were conducted with a total of eleven participants.

Table 11: Workshop Participants

Workshop Group Name	Participant Position	Experience in the Company	Responsible for Decision-Making for Software Purchase
WG1-Asia	Digital Innovation Director	+3 years	YES
	IT Group Lead	+3 years	YES
	Asia Analytics Lead	+5 years	YES
WG-Australia	Head of Finance Transformation	+3 years	YES
	ANJ IT Lead	+3 years	YES
	ANJ Analytics and Data Manager	+3 years	YES

WG-Latin and North America	IT-Analytics Manager	+3 years	YES
	LATAM IT- Big Data Manager	+3 years	YES
WG-Europe	Head of International IT	+10 years	YES
	IT Transformation Lead	+ 7 years	YES
	Finance Transformation Lead IT	+18 years	YES

The workshop groups are formed based on the regions of the company due to the time zone differences. The regions corresponding to each workshop group can be examined under the "Workshop Group Name" column in Table 11.

5.1.2. Overall Workshop Results

As mentioned in the Model Design part, every workshop group chose four criteria out of seven to test the model. The result is calculated by their scoring to each criterion and alternative with the AHP algorithm. As an outcome of the workshop, the AHP model that was developed suggested a decision for each workshop group.

The selected four criteria from each group and the suggested decision by the model can be examined in the table below. The chosen criteria are also sorted by the importance weighting calculated according to workshop participations' scorings. Therefore, the criterion in the first place is ranked as the highest importance compared to other criteria.

Table 12: Criteria Selection and Suggested Decision of Workshop Groups

Workshop Group Name	Selected Criteria (sorted by highest importance to lowest)	Suggested Decision by the Model
WG - Asia	1. IT Cost 2. IT Support 3. Flexibility 4. Collaboration Ability	Centralise
WG-Australia	1. IT Cost 2. Collaboration Ability 3. Flexibility 4. Innovativeness	Hybrid

WG -Latin and North America	1. Innovativeness 2. Integration Ability 3. IT Support 4. Flexibility	Hybrid
WG-Europe	1. IT Cost 2. Flexibility 3. IT Support 4. Innovativeness	Centralise

Most Selected Criteria by Each Workshop Group: The difference in importance of each criterion selected by each workshop group can be examined in Figure 12 below. The figure shows the difference based on the calculated weight of each criterion by the AHP calculations. The calculated weights can be seen on top of each bar corresponding to the selected criterion. The detailed weight calculations of the criteria of each workshop group can be examined in Appendix C.

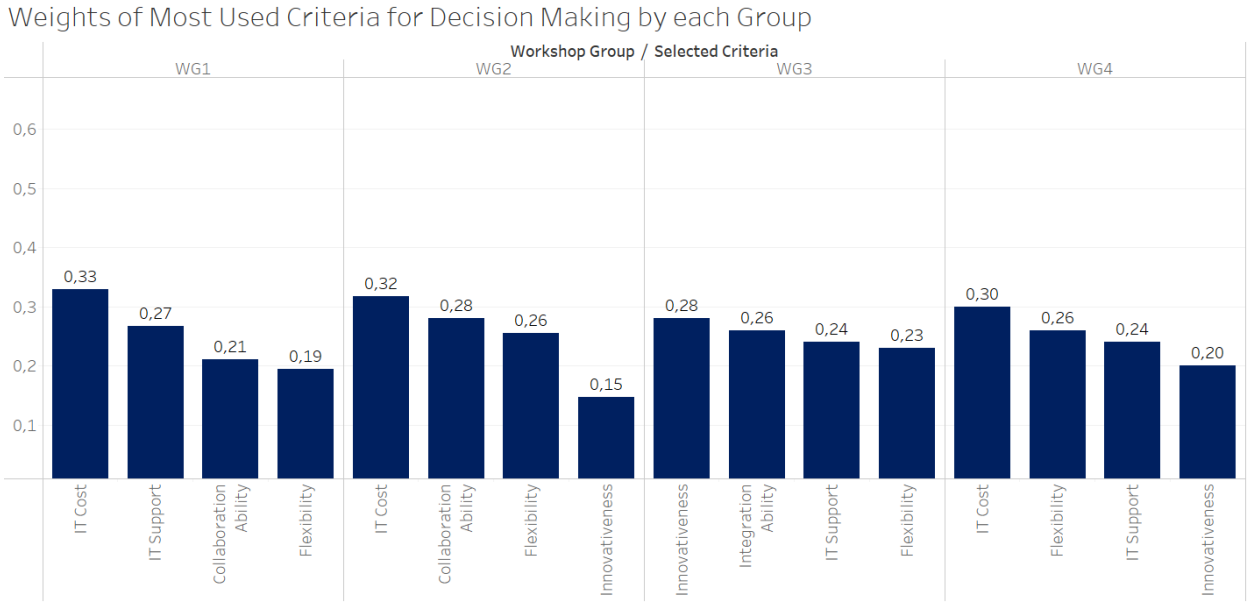

Figure 12: Importance Ranking of Selected Criteria by each Workshop Group

Overall Most Selected Criteria by Workshop Groups: The most selected criteria by the workshop participants are shown in Figure 13. According to the workshop groups, the most selected criterion is flexibility, and all the groups selected it. The least selected criterion is integration ability, which is selected by only one of the groups. Task completion speed is not selected in any of the workshops because the participants stated that task completion speed depends more on other factors than (de)centralisation of software applications. Therefore that criterion is not shown in Figure 13.

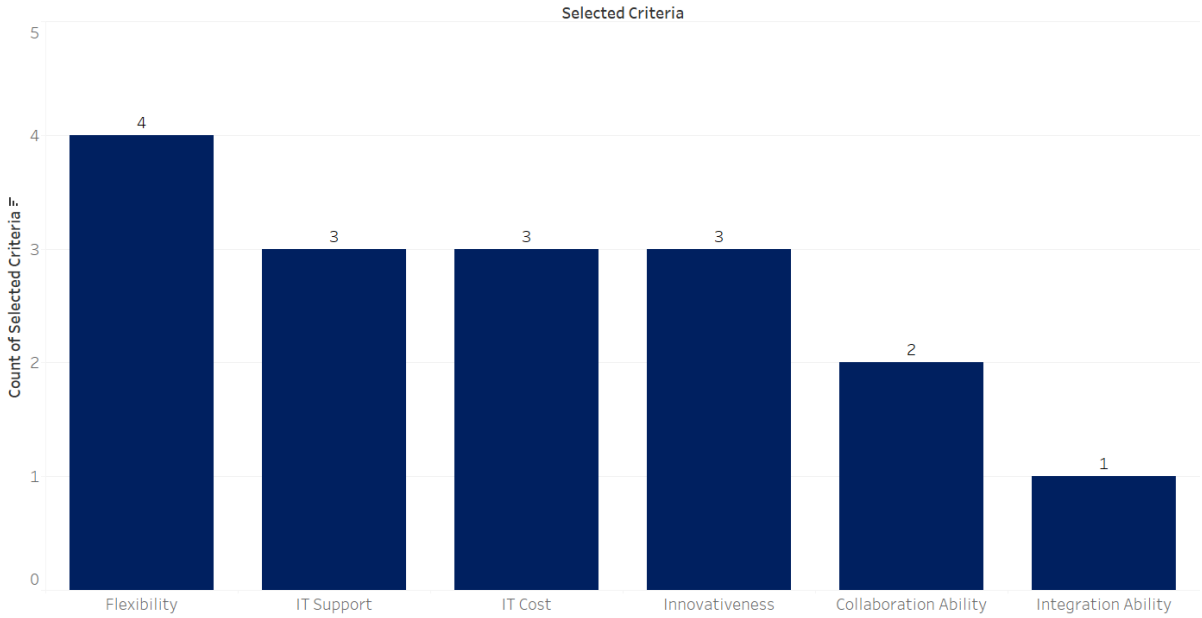

Figure 13: Most Selected Criteria by the Workshop Groups

Overall Importance Ranking for Criteria by Workshop Groups: The overall importance of selected criteria is calculated by taking the average of the selected criteria weights. Although the most selected criterion was flexibility, there are more important criteria for the workshop participants. The overall most crucial criterion is IT cost. The average weights of each criterion and the difference between them can be examined in Figure 14.

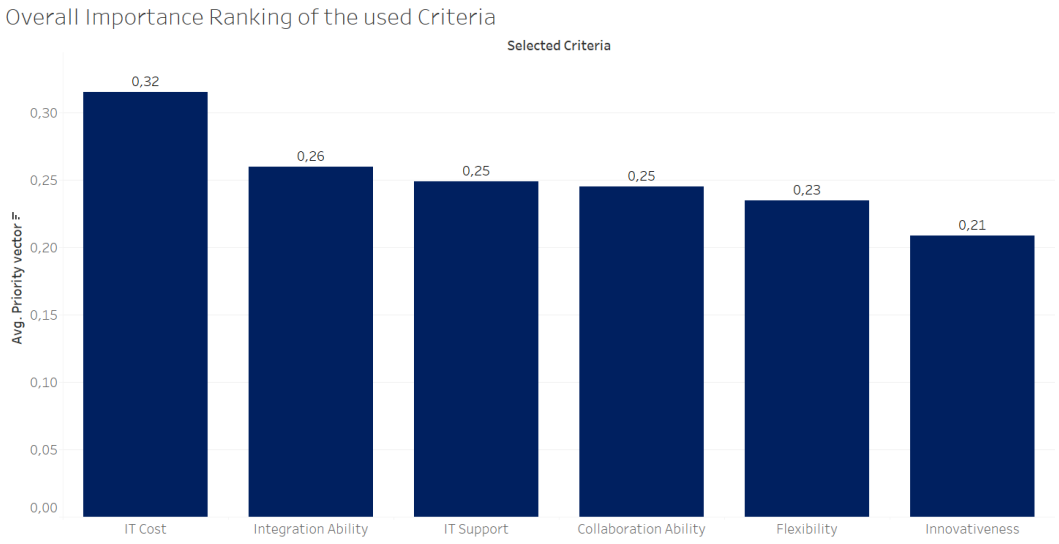

Figure 14: Average Importance Ranking of Selected Criteria

Overall Preferability of Alternatives for Each Criterion: The overall preferability of alternatives is calculated by taking the average alternative weights for each criterion. The best and worst alternative for each criterion and the difference in the alternative weights is shown in Figure 15. As seen in

Figure 15, centralisation is the best alternative for collaboration ability, IT cost and IT support. Decentralisation is the best alternative for integration ability. Lastly, hybrid is the best alternative for flexibility and innovativeness.

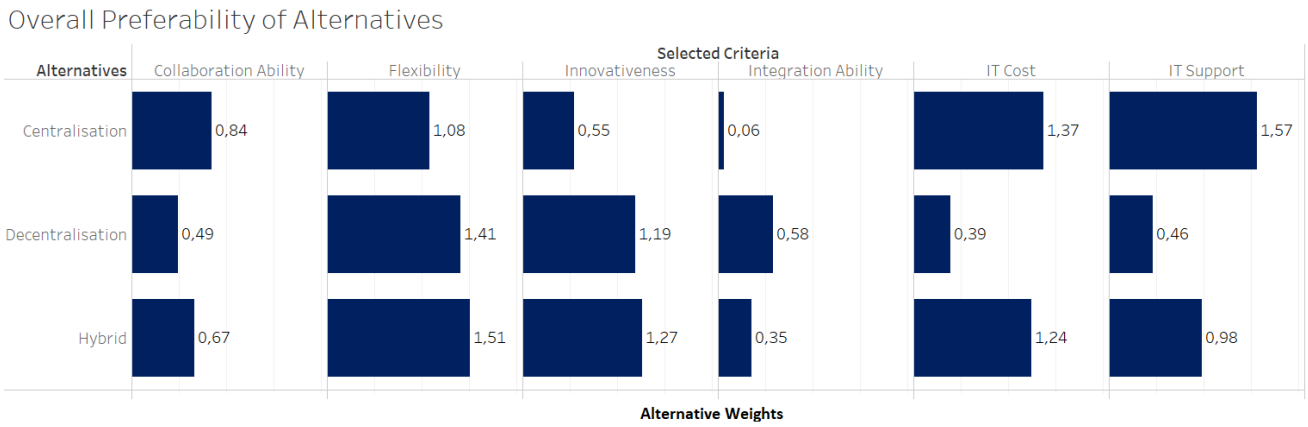

Figure 15: Overall Preferability of Alternatives

5.1.3. Overall Questionnaire Results

To assess the success of the designed model, a questionnaire was conducted for the workshop participants. The questionnaire is designed by a 1-5 Likert Scale, as explained in the Questionnaire Design section. All of the workshop participants filled out the questionnaire. The questions and proposed options to answer these questions are presented in Appendix A.

This section presents the results from the questionnaire in two parts.

Part I – Overall Satisfaction focuses on assessing the workshop participants' level of satisfaction with the decision-making model. As seen in Figure 16, this part consists of questions regarding satisfaction, ease of use, user interface and collaborativeness.

In Figure 16, the evaluated points are stated in the rows. The number of participants that answered Lastly, the answers of the participants are presented in different colours. The colour legend at the bottom right of the figure explains the meanings of the colours. The colours are not visible for the "Slightly satisfied" and "Not at all satisfied" options because they are not selected by any of the participants.

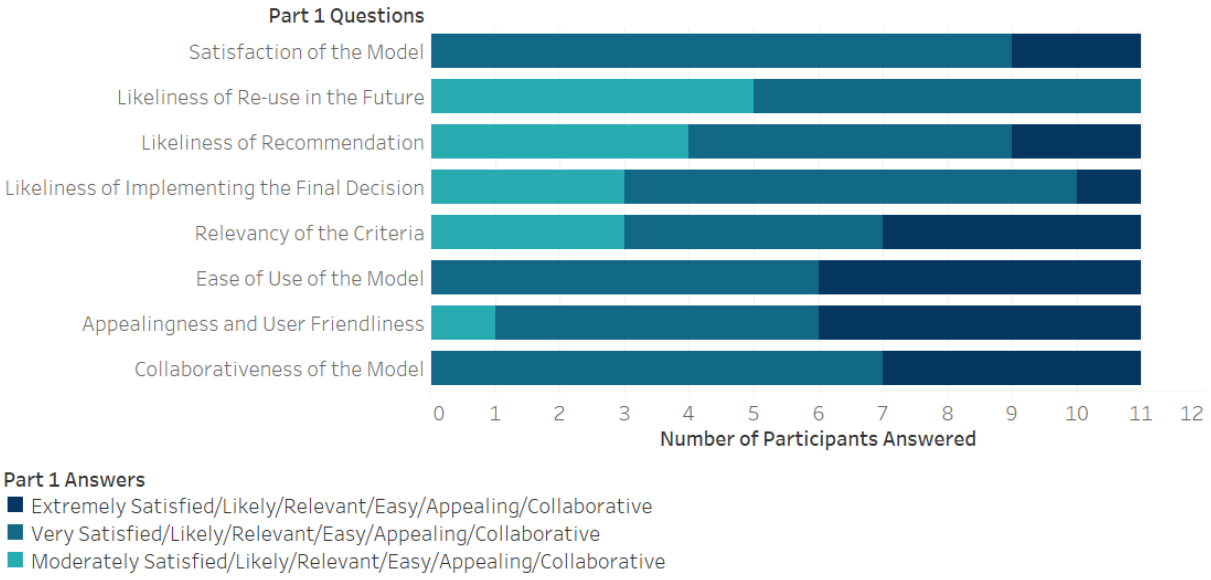

Figure 16: Survey Part 1 Results

Part II- Agreement with Statements focuses on assessing the impact of the model by asking agree/disagree questions. As seen in Figure 17, each of these questions is designed based on the study's objectives.

In Figure 17, the evaluated points are stated in the rows. The number of participants that answered Lastly, the answers of the participants are presented in different colours. The colour legend at the bottom right of the figure explains the meanings of the colours. The colour is not visible for the “Not at all agree” option because that option is not selected by any of the participants.

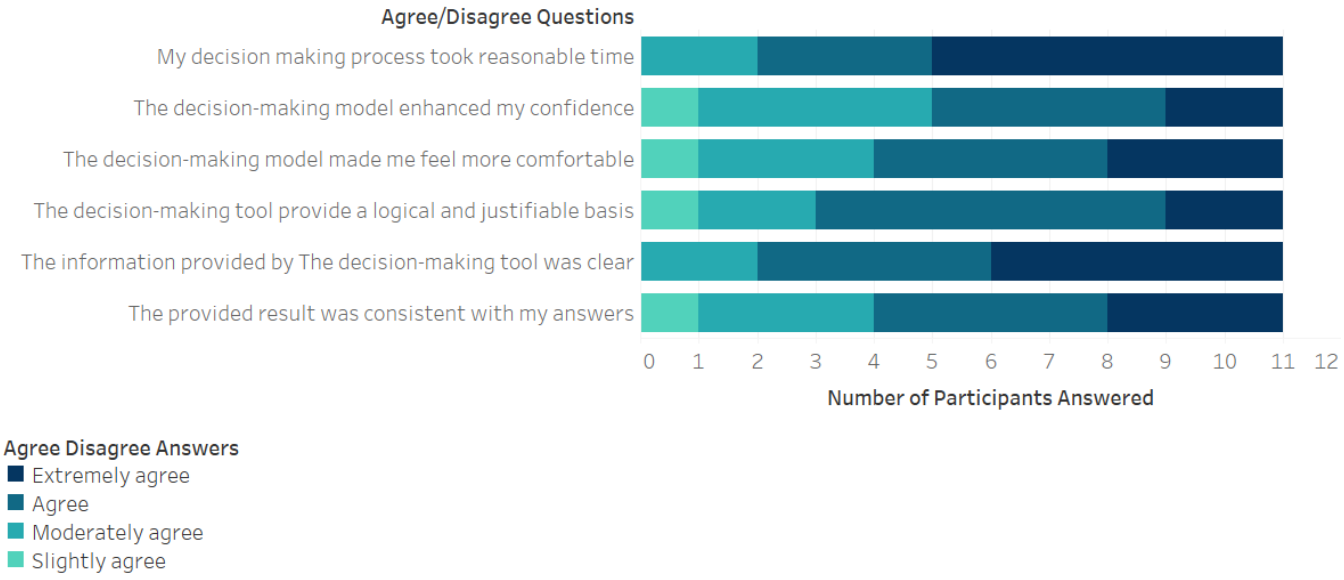

Figure 17: Survey Part 2 Results

The results from the third part of the questionnaire are not explained in this section. The third question was to provide additional feedback regarding the workshop and the model. However, not all the

workshop participants answered the last part. Therefore, part 3's results are explained separately for each workshop where available.

5.2. Researcher's Observations from the Workshops

In this section, the researcher's observations from the workshops are presented in bullet points. Although these observations might not directly relate to the study objectives, we thought they might be valuable for the discussion.

- Workshop Participants understand what they should do in each step easily.
- All the workshops were done within the given duration. None of the workshops run beyond the given duration.
- The researcher asked the participants regarding their experience with the AHP model at the beginning of the workshops. None of the workshop participants had any experience with AHP.
- All of the workshop participants knew the other participants in their group.

5.3. Case Results

Each workshop is analysed as a different case in this part of the study. Therefore, the results of the cases are presented separately.

5.3.1. Case A: Workshop Group Asia

The selected criteria and suggested decision by the model of workshop group Asia can be examined in the table below. Workshop group Asia's Miro answers are presented in Appendix B.

Table 13: Workshop Group Asia - Selected group and suggested decision

Selected Criteria (sorted by highest importance to lowest)	Suggested Decision by the Model
1. IT Cost 2. IT Support 3. Flexibility 4. Collaboration Ability	Centralise

The reason why these criteria are selected by the WG-Asia is explained below based on their feedback on the workshop :

1. **IT Cost:** WG-Asia stated that budget is the number one factor to consider for every purchasing decision. No decision can be made in a budget-absent situation. The group also highlighted that the region has many employees, and the higher the employees, the higher the

IT costs. IT cost differs when a software application is centralised or decentralised for tens of employees versus hundreds of employees. Therefore, IT cost has the first place.

2. **IT Support:** This criterion was also selected due to high employee numbers in the region, according to the workshop participants. From the participants' perspective, the more they need IT support, the higher the cost. Also, this cost is not only related to the money spent on IT support but also the time spent.
3. **Flexibility:** Customer needs can change rapidly; as one of the workshop participants suggested, the world is not waiting for any business, and the requirements can change swiftly. Therefore it is essential to be flexible and keep up with those new demands.
4. **Collaboration Ability**: Since there are many employees and they also work in cross-functional teams, it is crucial to have the ability to collaborate while using a software application. According to participants, most of the data visualisations and dashboards are an outcome of teamwork.

So, the WG-Asia was primarily focused on the number of employees that are going to affect by this decision. Since the number of employees is high in Asia, the workshop participants thought this significant number would influence the effect of each criterion. Therefore they selected these for the criteria above.

After selecting the four criteria, WG-Asia also ranked the alternatives (centralisation, decentralisation and hybrid). This ranking is made based on the preferability of alternatives by each criterion. Therefore, the participants ranked the alternatives four times based on the four criteria that they selected. As explained in the Model Design part, the alternative with the highest ranking means that the alternative is the best option for benefiting from the objective criteria. At the same time, the lowest is the worst option. WG-Asia's alternative ranking for each criterion is presented in the table below.

Table 14:Workshop Group Asia - Best and Worst Alternatives for each Criterion

	Criterion 1: IT Cost	Criterion 2: IT Support	Criterion 3: Flexibility	Criterion 4: Collaboration Ability
The best alternative to benefit from criterion	Centralisation	Centralisation	All alternatives have the equal weights	Decentralisation
The worst alternative to benefit from criterion	Decentralisation	Decentralisation	All alternatives have the equal weights	Centralisation

The detailed weights for each alternative based on participants' ranking can be examined in Appendix C.

According to all of these results and as mentioned in the first table, centralisation is the suggested decision for WG-Asia.

Lastly, the participants of WG-Asia provided additional feedback to evaluate the model. The key points of WG-Asia's feedback are as follows:

- Current criteria cover the general factors very well.
- In different or more specific decisions, additional criteria will be needed. The criteria are very likely to be changed in large companies because there might be unexpected factors that are needed to be considered throughout the process.
- The model is simple and easy to understand.
- The visualisation of the model is user-friendly.

5.3.2. Case B: Workshop Group Australia

The selected criteria and suggested decision by the model of workshop group Australia can be examined in the table below. Workshop group Australia's Miro answers are presented in Appendix B.

Table 15: Workshop Group Australia - Selected group and suggested decision

Selected Criteria (sorted by highest importance to lowest)	Suggested Decision by the Model
1. IT Cost 2. Collaboration Ability 3. Flexibility 4. Innovativeness	Hybrid

The reason why these criteria are selected by the WG-Australia is explained below based on their feedback on the workshop :

1. **IT Cost:** IT cost is selected as the most important criterion because, without the required budget, none of the decisions can be made, as one of the participants stated, "No money, no decision".
2. **Collaboration Ability:** Most teams work as cross-functional teams. Therefore, it is crucial for them to be able to work together.
3. **Flexibility:** Software flexibility is needed to address the changes in the market. According to the workshop participants, it is extremely difficult to predict the future of the market. Therefore, it is essential to be prepared for possible software feature switches.
4. **Innovativeness:** WG-Australia participants underlined the importance of innovativeness. Because according to them, all the new functionaries to satisfy the customers come from the

company's employees. They also mentioned that this is crucial to stay in the competition and customer satisfaction.

After selecting the four criteria, WG-Australia also ranked the alternatives (centralisation, decentralisation and hybrid). This ranking is made based on the preferability of alternatives by each criterion. Therefore, the participants ranked the alternatives four times based on the four criteria that they selected. As explained in the Model Design part, the alternative with the highest ranking means that that alternative is the best option for benefiting from the objective criteria. In contrast, the lowest ranking is the worst option. WG- Australia's alternative ranking for each criterion is presented in the table below.

Table 16:Workshop Group Australia - Best and Worst Alternatives for each Criterion

	Criterion 1: IT Cost	Criterion 2: Collaboration Ability	Criterion 3: Flexibility	Criterion 4: Innovativeness
The best alternative to benefit from criterion	Hybrid	Centralisation	Decentralisation	Hybrid
The worst alternative to benefit from criterion	Decentralisation	Decentralisation	Centralisation	Centralisation

The detailed weights for each alternative based on participants' ranking can be examined in Appendix C.

According to all of these results and as mentioned in the first table, centralisation is the suggested decision for WG-Australia.

Lastly, the participants of WG-Australia provided additional feedback to evaluate the model. The key points of WG-Australia feedback are as follows:

- Having a workshop is a very engaging experience to make a group decision
- The model was easy to understand and very user-friendly.
- The decision was made quickly.

5.3.3. Case C: Workshop Group Latin and North America

The selected criteria and suggested decision by the model of workshop group Latin and North America can be examined in the table below. Workshop group Latin and North America's Miro answers are presented in Appendix B.

Table 17: Workshop Group Latin and North America- Selected group and suggested decision

Selected Criteria (sorted by highest importance to lowest)	Suggested Decision by the Model
1. Innovativeness 2. Integration Ability 3. IT Support 4. Flexibility	Hybrid

The reason why these criteria are selected by the WG-Latin and North America is explained below based on their feedback on the workshop :

1. **Innovativeness:** WG-Latin and North American participants greatly emphasise this criterion because innovativeness is one of the key factors to staying in the competition. The participants think that innovativeness should be supported as much as possible among the employees. Since centralisation or decentralisation of the software application most likely have a different impact on this criterion, innovativeness should be the first factor for consideration.
2. **Integration Ability:** Integrating different applications is one of the most important criteria, according to the WG-Latin and North America participants. They mentioned that there are different types of software that are needed to work together. The participants added that this is especially crucial for data-related tasks because the software should be integrated with the data sources.
3. **IT Support:** Providing the required technical support is crucial to save time and cost. As participants discussed, the need for IT support can lead to operational delays. Therefore, adequate IT support is a must for operations to continue smoothly and effectively.
4. **Flexibility**: Different needs can occur unexpectedly. To manage those unexpected situations, having flexibility is necessary. The participants highlighted that late response to the changes leads to a loss of time and money.

WG-Latin and North America participants did not select IT cost on purpose. The participants stated that IT cost is the most essential criterion out of all; therefore, it will affect the whole decision. That is why the participants wanted to make this decision without the IT cost criteria to see the effect of the other criteria.

After selecting the four criteria, WG-Latin and North America also ranked the alternatives (centralisation, decentralisation and hybrid). This ranking is made based on the preferability of alternatives by each criterion. Therefore, the participants ranked the alternatives four times based on the four criteria that they selected. As explained in the Model Design part, the alternative with the highest ranking means that that alternative is the best option for benefiting from the objective

criteria, while the lowest ranking is the worst option. WG-Latin and North America's alternative ranking for each criterion are presented in the table below.

Table 18:Workshop Group America - Best and Worst Alternatives for each Criterion

	Criterion 1: Innovativeness	Criterion 2: Integration Ability	Criterion 3: IT Support	Criterion 4: Flexibility
The best alternative to benefit from criterion	Hybrid	Decentralisation	Centralisation	Hybrid
The worst alternative to benefit from criterion	Centralisation	Centralisation	Decentralisation	Centralisation

The detailed weights for each alternative based on participants' ranking can be examined in Appendix C.

According to all of these results and as mentioned in the first table, centralisation is the suggested decision for WG-Latin and North America.

5.3.4. Case D: Workshop Group Europe

The selected criteria and suggested decision by the model of workshop group Europe can be examined in the table below. Workshop group Europe's Miro answers are presented in Appendix B.

Table 19:Workshop Group Europe - Selected group and suggested decision

Selected Criteria (sorted by highest importance to lowest)	Suggested Decision by the Model
1. IT Cost 2. Flexibility 3. IT Support 4. Innovativeness	Centralise

The reason why these criteria are selected by the WG-Europe is explained below based on their feedback on the workshop :

1. **IT Cost:** Similar to the other workshop participants, WG-Europe also had a common opinion on IT costs. They suggested that cost is the first factor they consider for any decision. Because according to the participants, staying within the budget is a must.
2. **Flexibility:** According to the participants, the needs and tasks can change rapidly, and the software structure should be able to address that.

3. **IT Support:** WG-Europe participants discussed that every software in the company needs support to maintain the tasks. It must be considered while making this decision because the software (de)centralisation decisions can change the effectiveness of IT support.
4. **Innovativeness:** The employees need to create new solutions that can improve operations. This is essential to keep up with the market. The participants also added that if many tools are provided, this might increase the innovativeness of the employees.

After selecting the four criteria, WG- Europe also ranked the alternatives (centralisation, decentralisation and hybrid). This ranking is made based on the preferability of alternatives by each criterion. Therefore, the participants ranked the alternatives four times based on the four criteria that they selected. As explained in the Model Design part, the alternative with the highest ranking means that that alternative is the best option for benefiting from the objective criteria, while the lowest ranking is the worst option. WG- Europe's alternative ranking for each criterion is presented in the table below.

Table 20:Workshop Group Europe - Best and Worst Alternatives for each Criterion

	Criterion 1: IT Cost	Criterion 2: Flexibility	Criterion 3: IT Support	Criterion 4: Innovativeness
The best alternative to benefit from criterion	Centralisation	Decentralisation	Centralisation	Decentralisation
The worst alternative to benefit from criterion	Decentralisation	Centralisation	Decentralisation	Centralisation

The detailed weights for each alternative based on participants' ranking can be examined in Appendix C.

According to all of these results and as mentioned in the first table, centralisation is the suggested decision for WG- Europe.

Lastly, the participants of WG-Europe provided additional feedback to evaluate the model. The key points of WG-Europe feedback are as follows:

- More criteria can be added to the model for specific situations.

6.Discussion

In this part, the results from the questionnaire and workshops are discussed and linked with the previous studies where applicable. The discussion part is explained in five sub-chapters: (I) First section discusses the success of the model by comparing the model with the existing literature and the study results. (II) Then the used criteria are discussed to evaluate the criteria's relevance with the (de)centralisation decision-making. (III) Then the final (de)centralisation decisions the model suggests are discussed. (IV) After discussing the study's results, the recommendations for future research are explained. (V) Lastly, the limitations of the study are discussed.

6.1. Success of the Model

To achieve the main objective of this study, a decision-making model is designed to assist the re-occurring decision-making process of (de)centralisation of software applications. This model is designed due to the lack of decision-making models, particularly to (de)centralisation decisions of software applications in a company. To design a decision-making model, we decided to use an existing MCDM model that we can modify particularly for this study. After an extensive literature review on MCDM models, AHP is selected as a base model to be modified based on the study's objectives. The main reasons for selecting the AHP model are; it provides a weighting and guides the decision-makers on how to weigh the criteria to increase objectivity. The Decision-Making Model Design chapter presents a detailed explanation for this selection.

Few technology decision-making models, such as SAFe (Oren, 2023), CBA (Robinson, 1993), and The Four Forces of Marketing Operations (Brinker, 2018), are examined. However, these models had gaps that were mostly filled by this study.

First, the SAFe model cannot cover comprehensive criteria than what should be considered for software (de) centralisation decisions. Also, the criteria covered by the model have no weighting. Therefore, all the criteria have the same impact on the decision, even though their importance might differ for different enterprises. The AHP model enables it to cover more criteria, and it is possible to add new criteria in the future. It also provides weighting for the criteria, so the more essential criteria affect the decision more.

Second, the CBA was unsuitable for the software (de)centralisation decision because it does not provide any guidance on qualifying the cost and benefit as a financial value for the criteria. However, the designed model compares the criteria based on their importance and the alternatives' effect on them. Hence, it eliminates the need to quantify the cost and benefit of the criteria.

The four forces of the marketing operations model suggested centralising for scaling and decentralising to gain speed (Brinker, 2018). Although this model provides a concept for deciding whether to centralise or decentralise, the scope is too narrow because it only makes suggestions based on two criteria. To expand the area this model focuses on, this study's model covers more criteria that can influence the decision.

The Technology Decision Making Approach (Ilori et al., 1997) and IT purchasing Framework (Luzzini et al., 2014) provide insight into how technology decisions are made rather than a decision-making model. Therefore, these models are not suitable for facilitating the decision-making process. Nevertheless, these models can be used to understand the decision-making process and final decision.

Although the decision-making process took a reasonable time by using AHP according to the study's results, as seen in Figure 17, AHP still requires a considerable amount of time due to its number of steps. Since the number of steps increases when the number of criteria increases, AHP is a time-consuming model for decisions with numerous criteria, especially when compared with a decision-making model with fewer steps, such as WSM.

In addition to covering the gaps mentioned above in previous studies, there were other findings in this study. One of the points observed was ease of use. Although none of the participants had previous experience with AHP, they had no problem understanding the tool, and they even stated it was an easy model to use (see Figure 16 and Figure 17). The decision-making tool is visualised by Miro instead of Excel to make the interface more user-friendly. Miro also made it easier to facilitate a workshop because of its timer and voting features. The timer feature enabled participants to manage their time efficiently; therefore, every group was able to finish using the model at the end of the workshop duration. The voting feature allowed each participant to state their opinions. Also, the AHP calculations were not visible to the participants, making the results more understandable. They only needed to complete the steps on Miro without considering the AHP algorithm's complexity. So the AHP model is not designed in a classical way but in a more user-friendly way to increase understandability and usability.

In addition to those findings, as a nature of the workshops, the participants could see the ranking of the other participants and discuss their ideas together. This provided a highly collaborative group decision-making environment (see Figure 16). During the workshops, we observed that this collaborativeness also led participants to influence their colleagues' input. This result supports the research that suggests the pressure from colleagues influences the decision-maker's decision as an external factor (Ilori et al., 1997)

This section also answers the first research question that is presented below.

RQ1: *"Can a model be developed to support such multi-criteria decision-making regarding software applications?"*

According to the workshop observations and questionnaire answers, the developed model is suitable for assisting software (de)centralisation decisions of the companies. In conclusion, it is possible to develop an easy-to-use and user-friendly model to support the companies in the decision-making process to make the decision-makers feel more confident and comfortable regarding their decisions, as shown in Figure 17.

6.2. Used Criteria for Decision-Making

One of the main aims of this study is to determine the factors that affect (de)centralisation decision making. These factors are addressed in the literature review, and we decided on seven factors that can be used as the criteria in the MCDM model. This section compares the study results and findings from the literature review regarding those seven factors.

Innovativeness

Innovativeness is one of the most selected criteria by the workshop participants to be considered while making the (de)centralisation decision. Participants selected innovativeness because it supports the creativity of the employees. This statement is also supported by Nell et al. (2021) and Ilori et al. (1997), by stating that innovativeness increases creativity and facilitates new product, solution and service design. According to the study results, a hybrid software application portfolio is the best approach to provide innovativeness. Daoping et al. (2016) and Nell et al. (2021) also find similar results by suggesting that multiple software application usage is best for innovativeness. The worst decision for innovativeness is centralisation. Blind et al. (2017) suggest that there is a negative relation between innovativeness and the centralisation of software applications which supports this study's findings. So, the study results for innovation are highly similar to previous studies.

Flexibility

Flexibility is the most selected criterion of this study. Flexibility is essential to address the rapidly changing needs of the customers, according to the workshop participants. Based on the study results, the hybrid approach is the best decision for providing flexibility. Magnusson's (2013) research supports this finding by suggesting that more tools are needed to keep up with the market changes. The study found that centralisation is the worst alternative for flexibility. However, Ahlemann et al. (2022) support the opposite. They claim that centralisation is the best decision to provide flexibility. Ahlemann et al. (2022) also present a condition to achieve this result. Only if the centralised software

application is adaptable to the market changes then, centralisation can be a better alternative for accomplishing flexibility.

IT Support

The workshop participant agreed that IT support is a relevant criterion for (de)centralisation decisions of software applications. The reason is mostly due to well-managed IT support's time and cost efficiency. In order to provide efficient IT support, centralisation is the best option since it is easier to provide support for a software rather than providing it for multiple software. Thus, the worst alternative is decentralisation for benefiting from IT support. The difference between the preferability of these alternatives can be examined in Figure 15. These findings are aligned with the previous studies. Parson et al. (2014) and Magnusson (2013) also suggest that selecting a centralised software application approach is the better alternative in order to benefit from IT support.

Integration Ability

Although integration ability is one of the least selected criteria, it still has a high effect on the decision compared to the other criteria. Centralisation of software applications is a better option for integration ability because only a single software will be integrated with different units instead of integrating it for various tools (Sklyar et al., 2019; Akkermans et al., 2002). However, this study shows the opposite. According to workshop results, integration ability is higher when the software applications are decentralised. The reason can be due to the small number of workshop participants because only one group selected this criterion, and it could be better to evaluate more feedback regarding this criterion. Alternatively, this result can be valid particularly for data visualisation tools since the data can be obtained from many different sources. So, the effect of (de)centralisation decision on integration ability could depend on the type of software.

Collaboration Ability

Akkermans et al. (2022) and Sklyar et al. (2019) claim that collaboration ability is a criterion that should be considered for this decision. The reason is that employees must use the same centralised software applications to work with their co-workers. So, they suggest centralisation is the best for increasing collaboration ability. This study also supports these findings. According to this study, centralisation is the best alternative for collaborating on software applications.

Task Completion Speed

According to this study’s results, task completion speed is not one factor that affects (de)centralisation decisions of the software applications in an enterprise. According to different literature, this factor has the opposite effect on the decision. According to Zmud (1982), decentralisation is the best decision for high speed, while Parson et al. propose the opposite and suggest centralisation as the best decision.

However, it is not even one of the selected criteria for this study because the study's participants claimed that task completion speed depends more on other factors rather than (de)centralisation of software applications. Therefore, there are no insights regarding the best decision for task completion speed. This result might be because of company-specific reasons such as company culture and prioritisation of the company.

IT Cost

IT cost is the most important criterion that affects the decision most. According to this study, centralising the software applications is the best alternative to reduce IT costs. Therefore, if the IT cost is the most important criterion, the model is more likely to suggest centralisation. Similarly, Schuff et al. suggest that centralising the software applications reduces IT cost by 50% (2021). Also, Akkermans et al. (2022) and Ahlemann et al. (2022) conclude with similar findings and suggest centralisation to lower IT cost. Lastly, the worst decision for IT cost is decentralisation, and there is a significant difference in the preferability of centralisation over decentralisation. This difference can be examined in Figure 15. To support this finding, Magnusson (2013) also suggests that decentralisation increases the IT cost, which is the worst option for low IT cost.

This section also answers the second research question that is presented below.

RQ2: "*What factors affect the decision-making of centralisation or decentralisation of the software applications used in a multinational company?"*

According to the reviewed literature and this study's workshop results, six factors affect the (de)centralisation decision-making. These factors are innovativeness, flexibility, IT support, integration ability, collaboration ability, and IT cost. Additional to these results, workshop participants confirmed the relevancy of these criteria to the (de)centralisation decision-making by their questionnaire results. The questionnaire result regarding the criteria relevance can be observed in Figure 16.

Furthermore, the results of this study also asses the importance ranking of each criterion as an additional finding. According to the workshop participants, the importance order of the criteria is as follows: IT cost, integration ability, IT support, collaboration ability, flexibility, and innovativeness. The ordering is from the most important to the least important criteria. The detailed visualisation of criteria and their importance weights can be examined in Figure 14.

6.3. Final Decisions

In this sub-section, the final decision suggested by the model is discussed. Although finding the best (de)centralisation decision is not one of this study's aims, these findings are presented as additional findings.

The best decisions suggested by the model were centralisation and hybrid approach for the software applications for different regions. The detailed results can be examined in Table 12. Akkermans et al. (2002) suggest that there is no one-fits-all decision for companies. Moreover, this study shows that the same (de)centralisation decision may not even fit every region in the same company.

Although there is no single best decision for a company, this research shows that decentralisation can be considered the worst option for software applications. The downsides of decentralisation outweigh the benefits. Therefore, it was not suggested to any of the workshop groups. In conclusion, a hybrid approach is better than decentralising the software applications company-wide.

6.4. Recommendations

This sub-section explains the recommendations for future related studies. The recommendations are as follows:

1. **Additional criteria**: Although the participants of the study were mostly satisfied with the criteria that were selected for this study, there was also feedback regarding the criteria being general. The criteria might need to change to evaluate other software application types. Also, specific company criteria might need to be addressed while making this decision. Therefore, more criteria precise to the situation or the enterprise can be added in future research.
2. **Different technology decision making:** this model can also be tested for various technology decision makings by updating or modifying the model where necessary. This decision making model is focused on the (de)centralisation of software applications. However, the model can also be tested for technology decision-making, such as hardware (de)centralisation.

6.5. Limitations

This sub-section explains the limitations of the study. This study has a few limitations, as follows:

1. **Subjectivity of the researcher:** The researcher made a great effort to be objective. However, the possibility that the decisions made in the research process are influenced by personal bias cannot be ignored.
2. **The design depends on the designer's skills:** Although an extensive literature review is conducted for designing the model, the quality still depends on the researcher's skills. Especially

for the visualisation part of the study since the researcher is not a UX/UI design expert. Still, the utmost effort is provided to design a user-friendly decision making model.

3. **Questionnaire instead of interviews:** The questionnaire provided rapid feedback from participants to prevent them from forgetting the workshop. Because it was a must to schedule another meeting with the participants for an interview since the participants had very limited ability, scheduling another meeting was difficult and impossible for a close date. Although the questionnaire provided rapid and straightforward feedback to address these issues, unlike an interview, the participants could not collaborate more on the questions.
4. **Time and availability limitations:** The participants of the study were from senior management. Therefore, the participants were very busy and had limited availability. This resulted in time-restricted workshops.
5. **Small workshop groups:** Having a small number of participants in each workshop is a result of the time and availability limitations that are explained above. More participants could have added more perspectives and potential to brainstorm different ideas. Therefore, the small number of participants also limits the generalizability of the research.

7. Conclusion

This research had two main objectives that can be reached by answering the two research questions. The first is developing a decision-making model to help enterprises to decide whether they should use a single software application for the same task by centralisation or multiple applications by using decentralisation. To achieve this objective, a base multicriteria decision-making model is selected. This selected model can be modified according to this study by conducting the literature review. After an extensive literature review and considering many decision-making models, AHP is selected as the base model of this study. Then, AHP is modified with the study's alternatives and criteria and specifically designed for this study. To evaluate the model, the AHP model was visualised, and workshops were conducted. A total of eleven KHC employees from the senior management joined the workshops and gave feedback during the workshop and afterwards by answering the questionnaire.

The second objective of this research is to address the factors that should be taken into account when deciding whether to centralise or decentralise the software applications used in the company. According to the extensive literature review, seven factors have been selected. These seven factors are as follows: Innovativeness, flexibility, IT support, integration ability, collaboration ability, task completion speed and IT cost. According to the workshop results, we found out that IT cost is the most crucial criterion, and innovativeness is the least important criterion for the workshop participants. Based on the results of workshops, task completion speed is not one of the factors that must be considered.

The designed decision-making model provides a collaborative, user-friendly, easy-use model that increases the decision-maker's confidence and comfort. Also, the considered criteria for this study were found relevant by the workshop participants. Lastly, the literature review and study results are mostly aligned for the determined criteria and the decision's effect on them.

As a result, we found that the designed decision-making model can help facilitate the decision-making process of the decision-makers for (de)centralisation decisions of software applications by covering the gaps of previous technology decision-making models.

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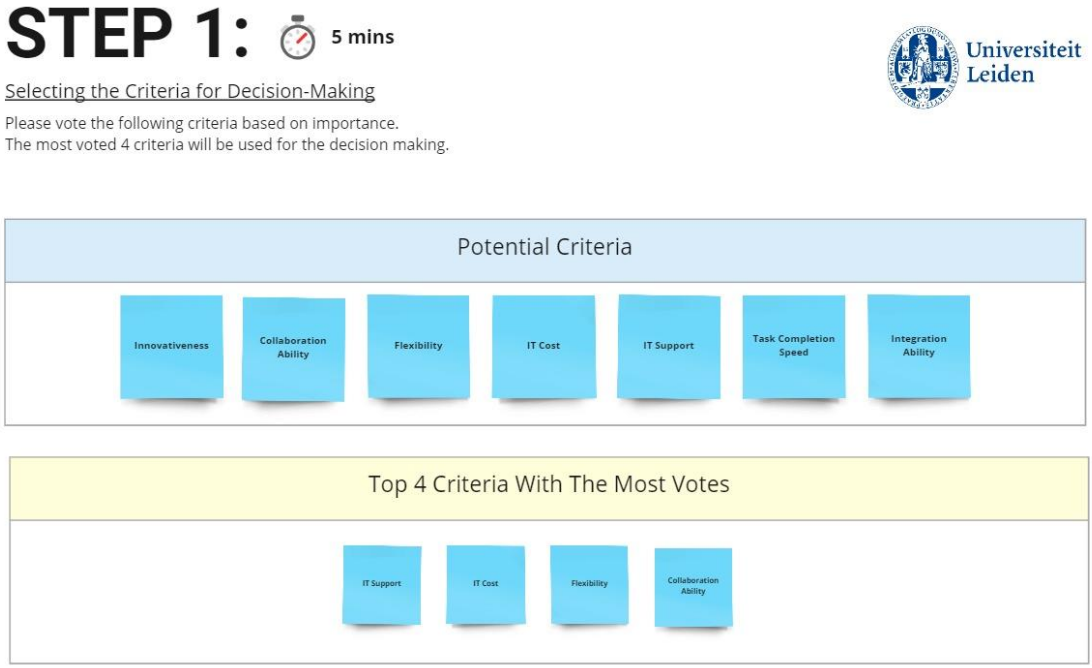
Appendix A: Questionnaire Questions

Survey Section	Question	Options
Part 1	How satisfied are you with the decision-making model that you tested?	a) Not at all satisfied b) Slightly satisfied c) Moderately satisfied d) Very satisfied e) Extremely satisfied
	How likely are you going to use this model in the future for decision-making?	a) Not at all likely b) Slightly likely c) Moderately likely d) Very likely e) Extremely likely
	Would you recommend this model to a colleague?	a) Not at all likely b) Slightly likely c) Moderately likely d) Very likely e) Extremely likely
	How well did the decision-making model incorporate criteria that were relevant to your decision?	a) Not at all relevant b) Slightly relevant c) Moderately relevant d) Very relevant e) Extremely relevant
	How likely are you going to implement the outcome decision in the enterprise?	a) Not at all likely b) Slightly likely c) Moderately likely d) Very Likely e) Extremely likely
	How visually appealing and user-friendly was the interface of the decision-making model?	a) Not at all appealing b) Slightly appealing c) Moderately appealing d) Very appealing e) Extremely appealing
	How easy was it to navigate and use the decision-making tool?	a) Not at all easy b) Slightly easy c) Moderately easy d) Very easy e) Extremely easy
	How collaborative was the decision-making model?	a) Not at all collaborative b) Slightly collaborative c) Moderately collaborative d) Very collaborative e) Extremely collaborative
Part 2	The decision-making model enhanced my confidence in the decision-making process.	a) Not at all agree b) Slightly agree c) Moderately agree d) Agree e) Extremely agree
	The decision-making model made me feel more comfortable with the decision-making process.	
	My decision-making process took reasonable time using this model.	
	The information provided by The decision-making tool was clear and understandable.	
	The provided result was consistent with my answers.	
	The decision-making tool provides a logical and justifiable basis for my decision.	
Part 3	Do you have any additional comments/feedback?	Open-ended

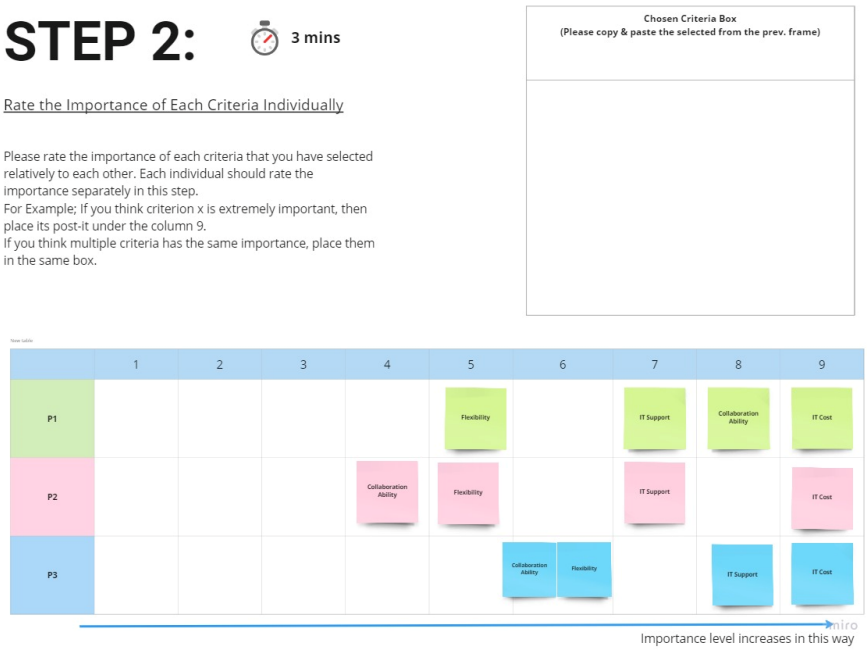
Appendix B: Miro Answers of Each Workshop Group

WG-Asia

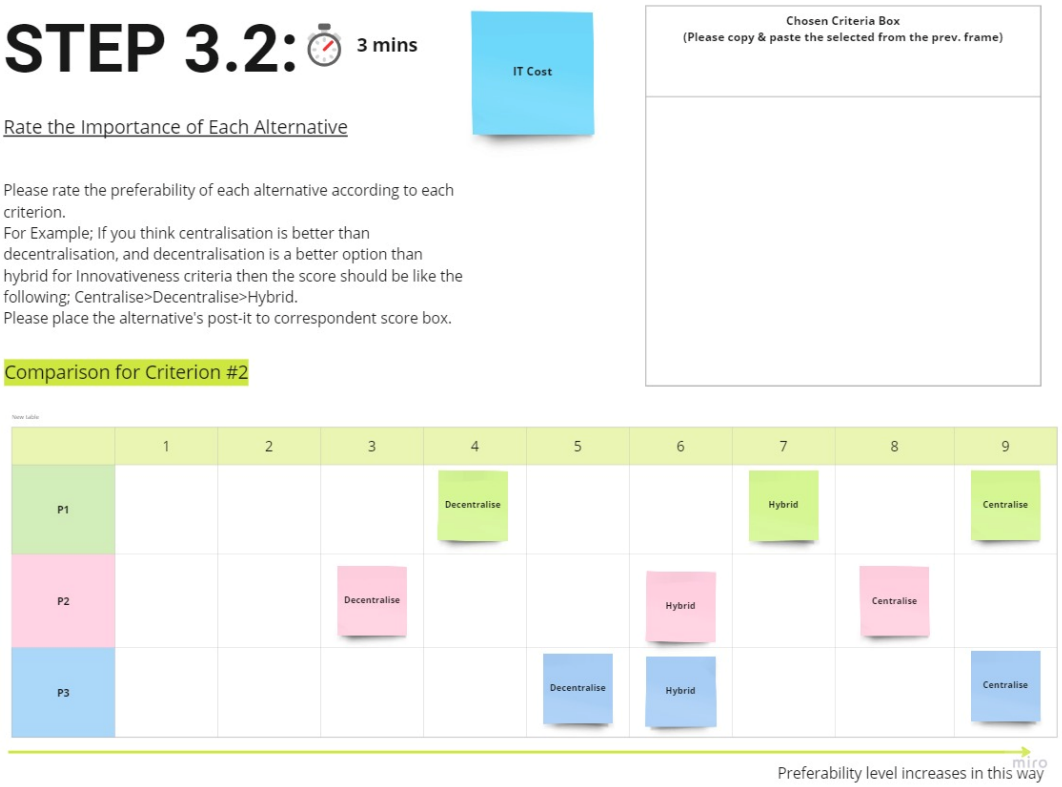
Selected Criteria

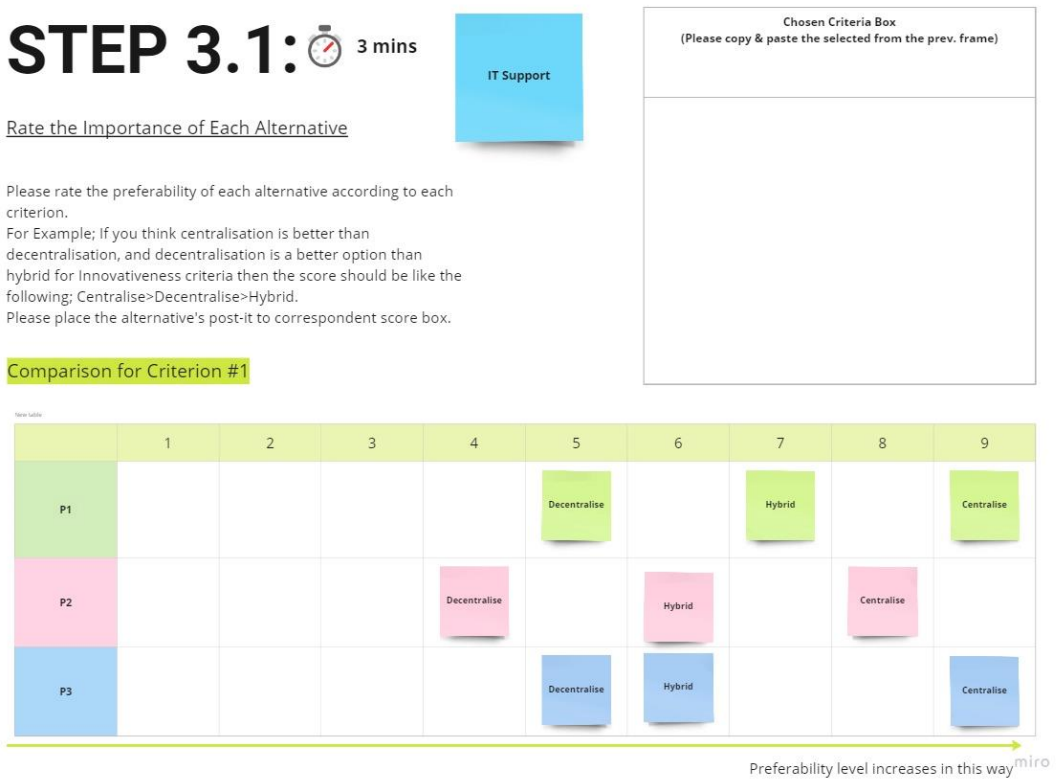


Criteria Weighting



Alternative Weighting for Each Criterion





STEP 3.3: 3 mins

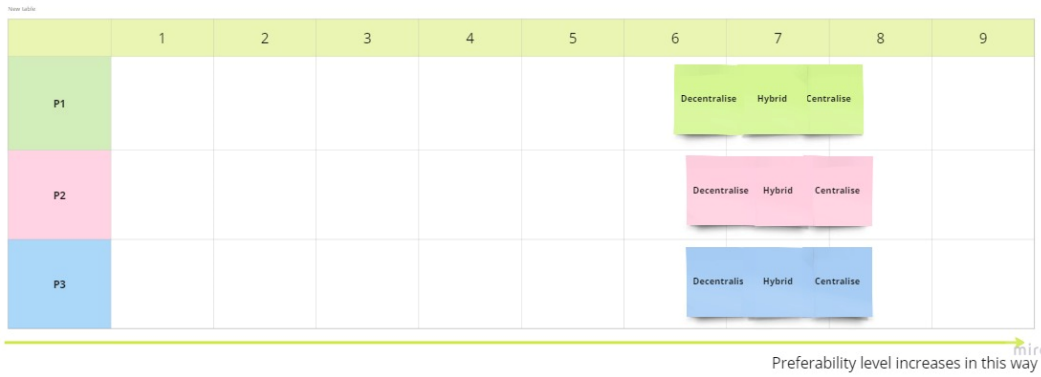
Flexibility

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #3



STEP 3.4: 3 mins

Collaboration Ability

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

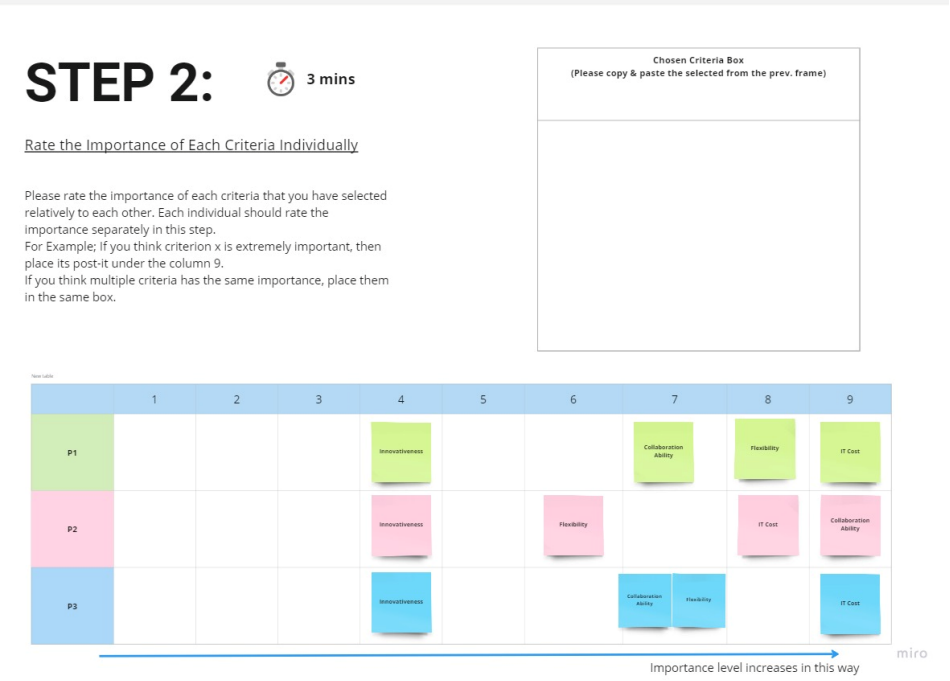
Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #4

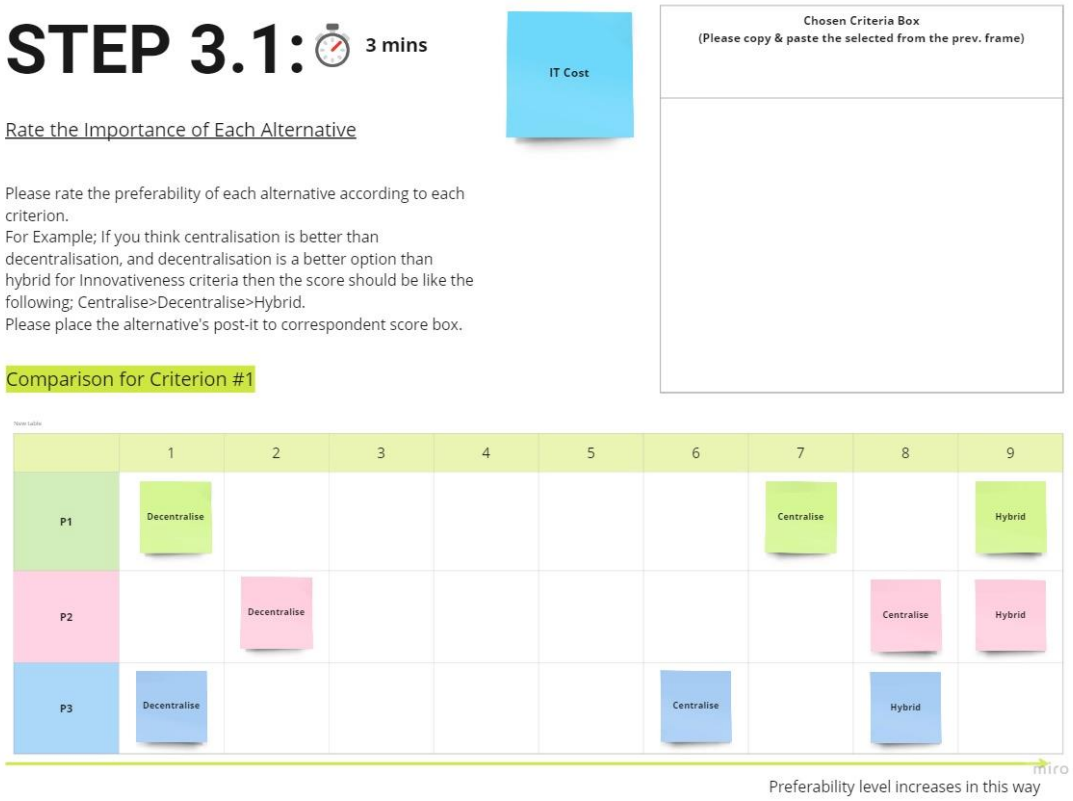
WG-Australia

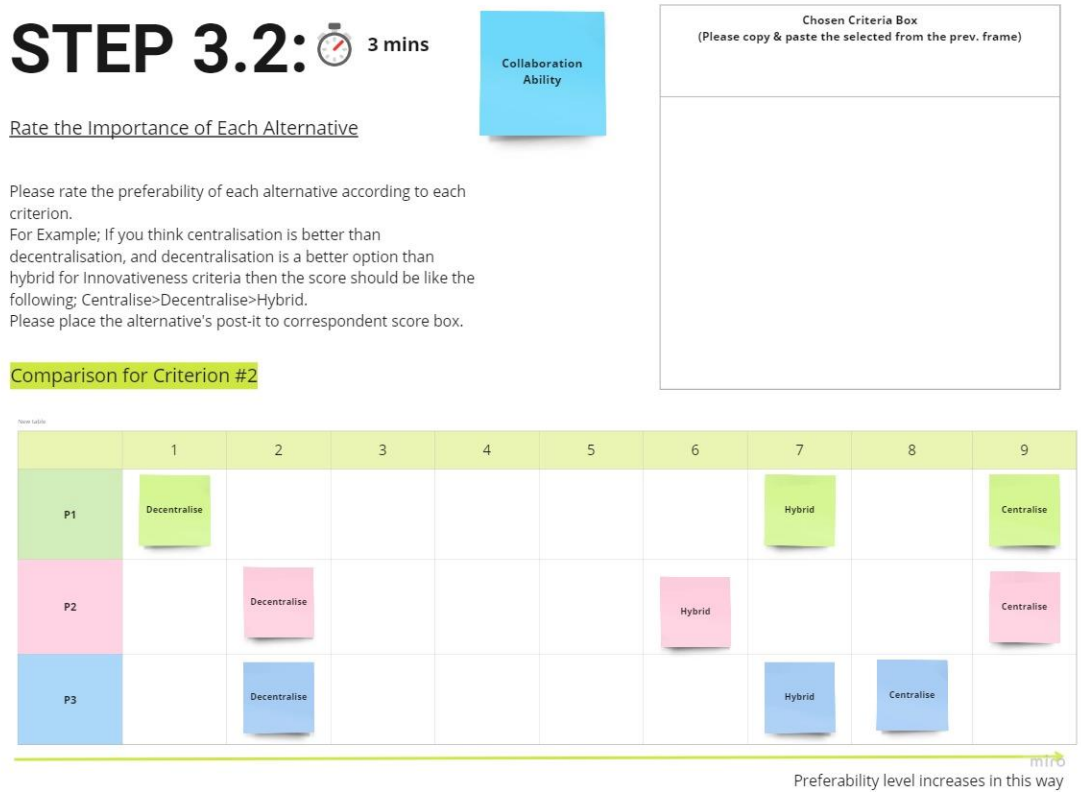
Selected Criteria

Criteria Weighting



Alternative Weighting for Each Criterion





STEP 3.3: 3 mins

Innovativeness

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #3

Preferability level increases in this way

STEP 3.4: 3 mins

Flexibility

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

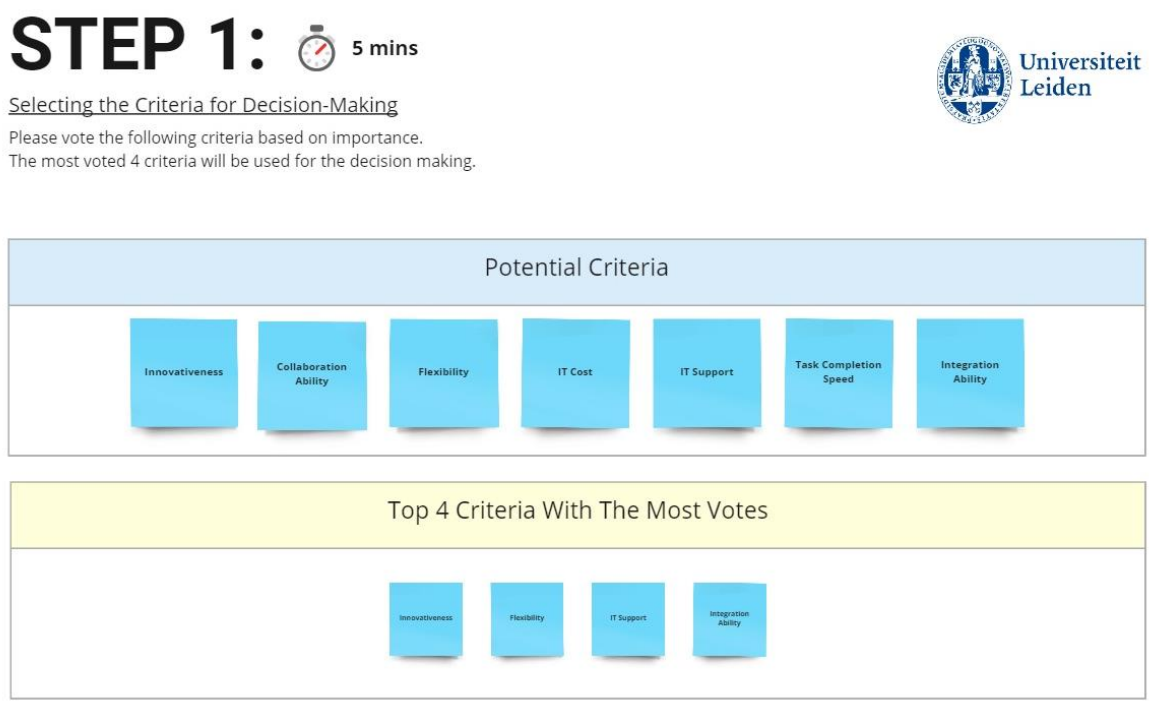
Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #4

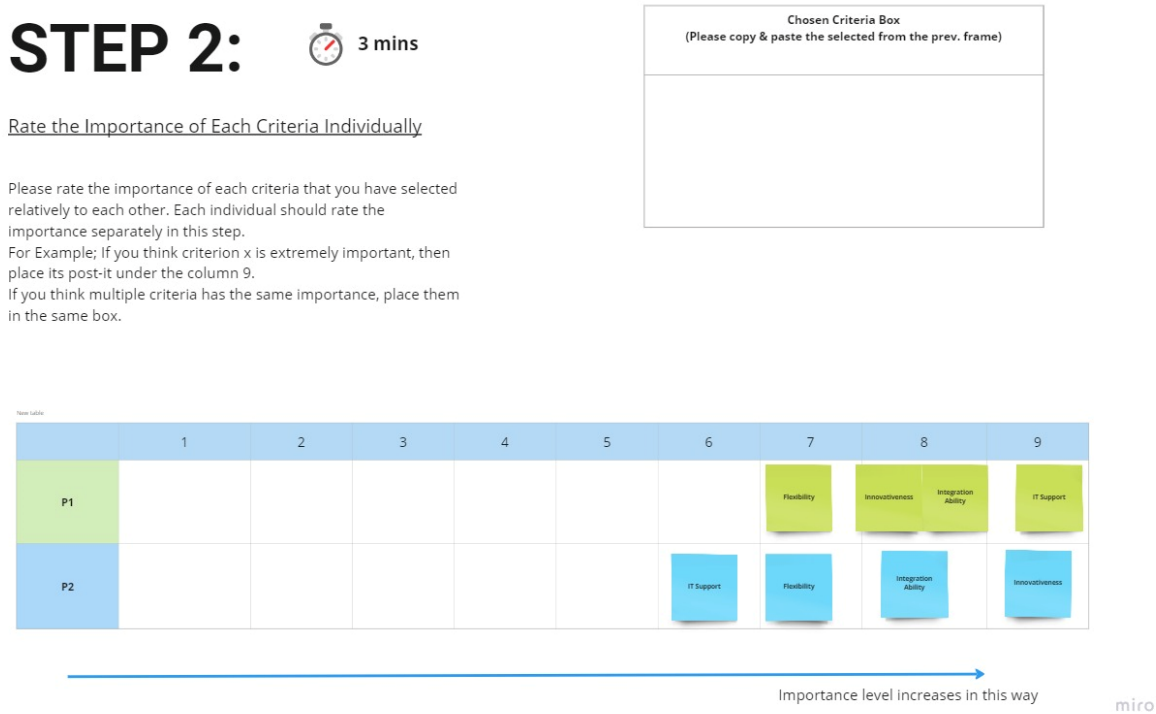
Preferability level increases in this way

WG-Latin and North America

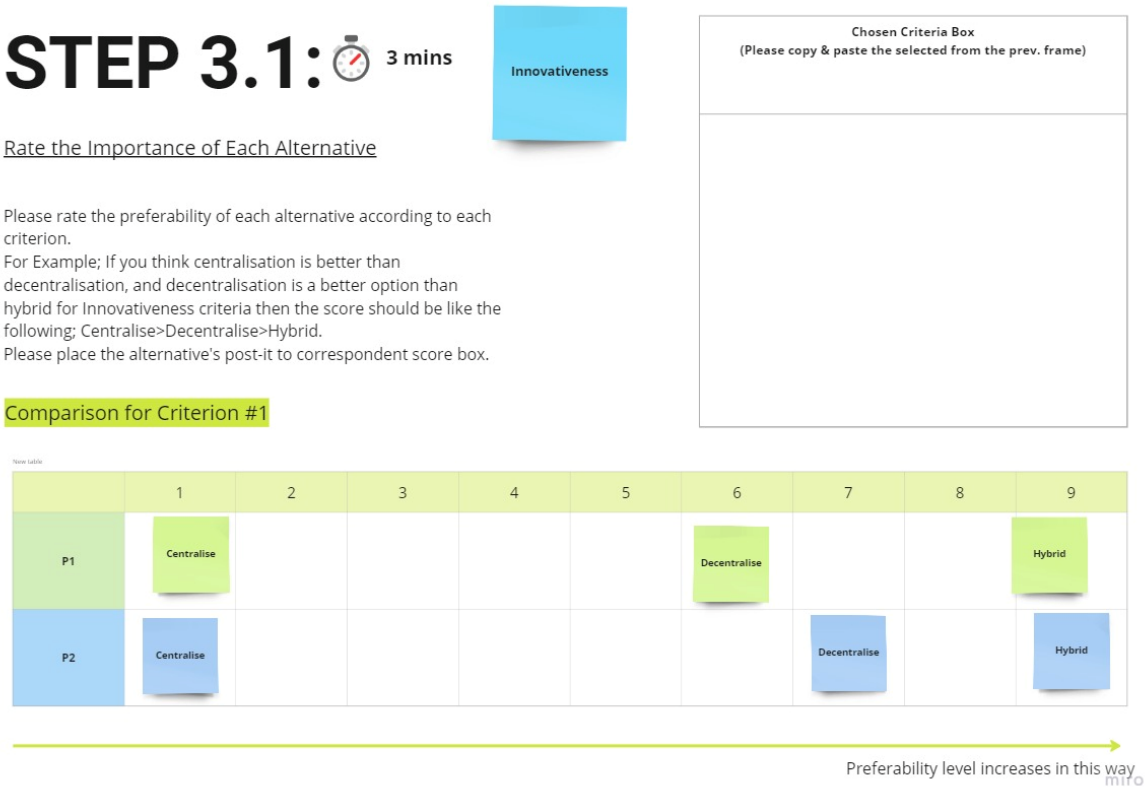
Selected Criteria

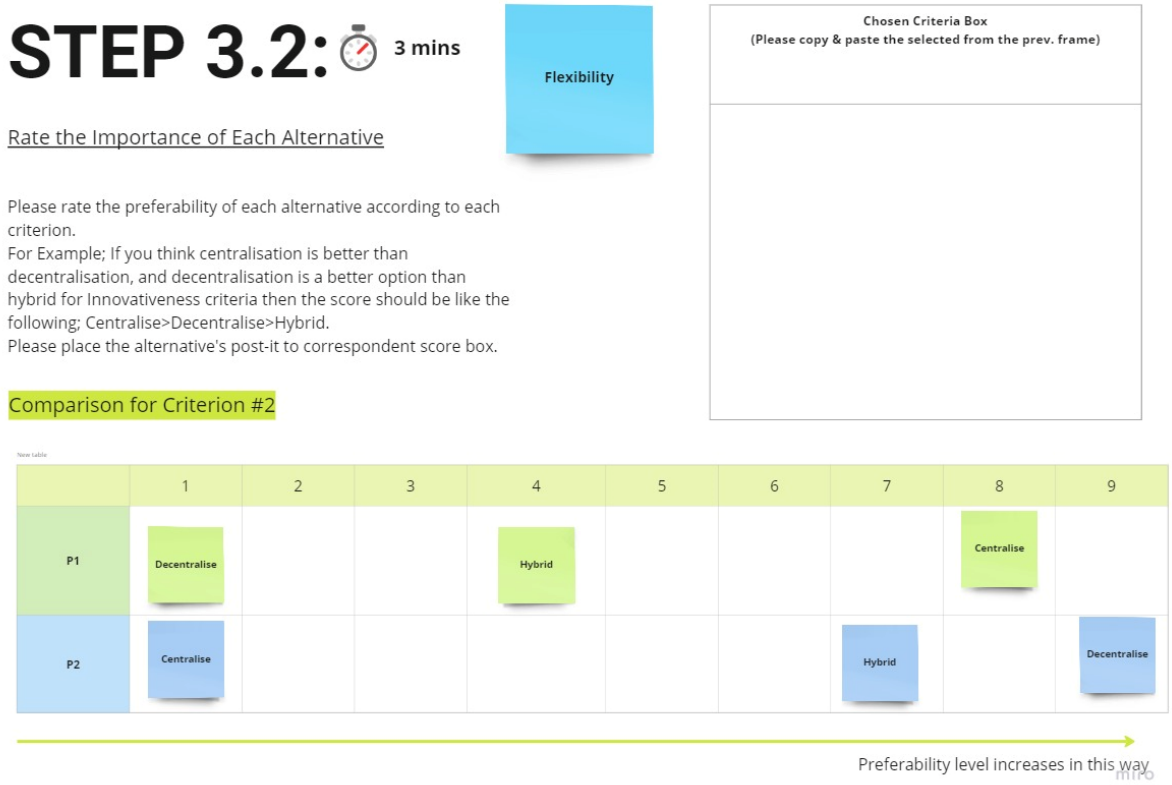


Criteria Weighting



Alternative Weighting for Each Criterion





STEP 3.3: 3 mins

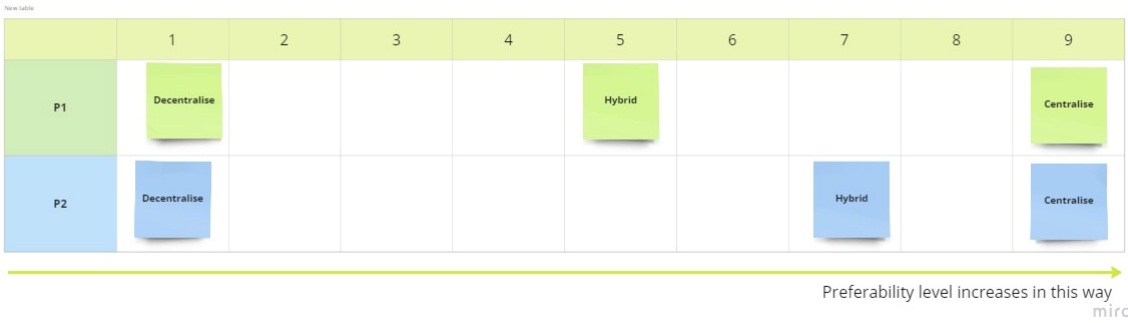
IT Support

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #3



STEP 3.4: 3 mins

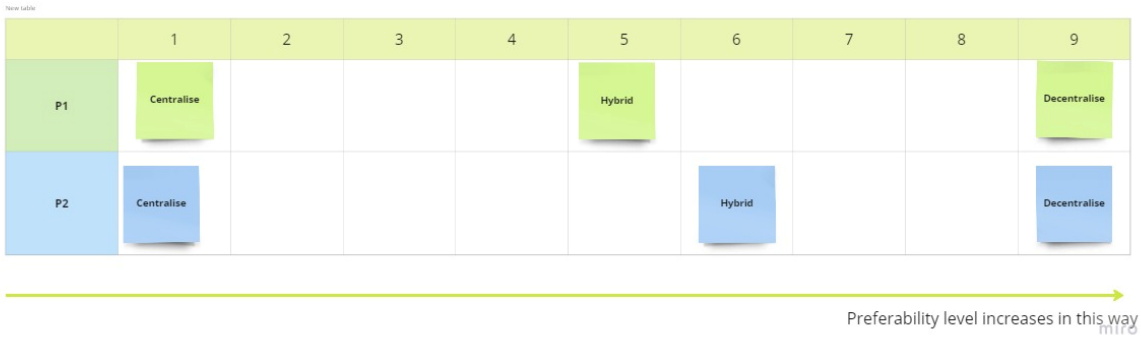
Integration Ability

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

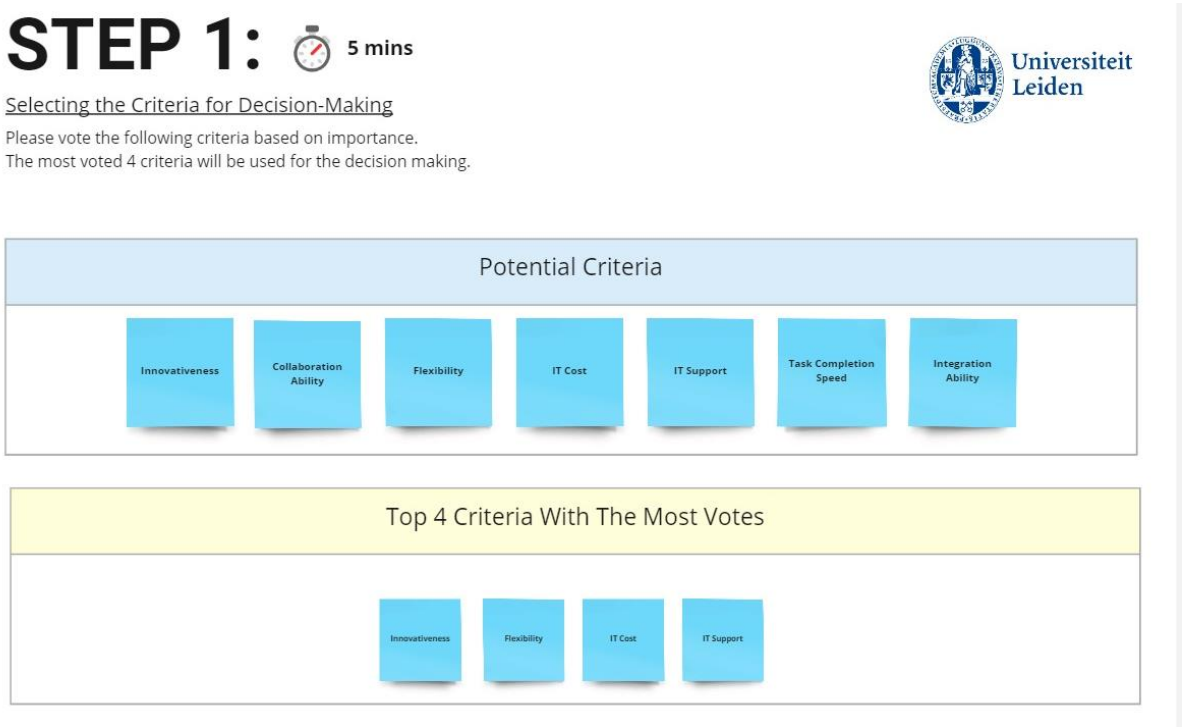
Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #4

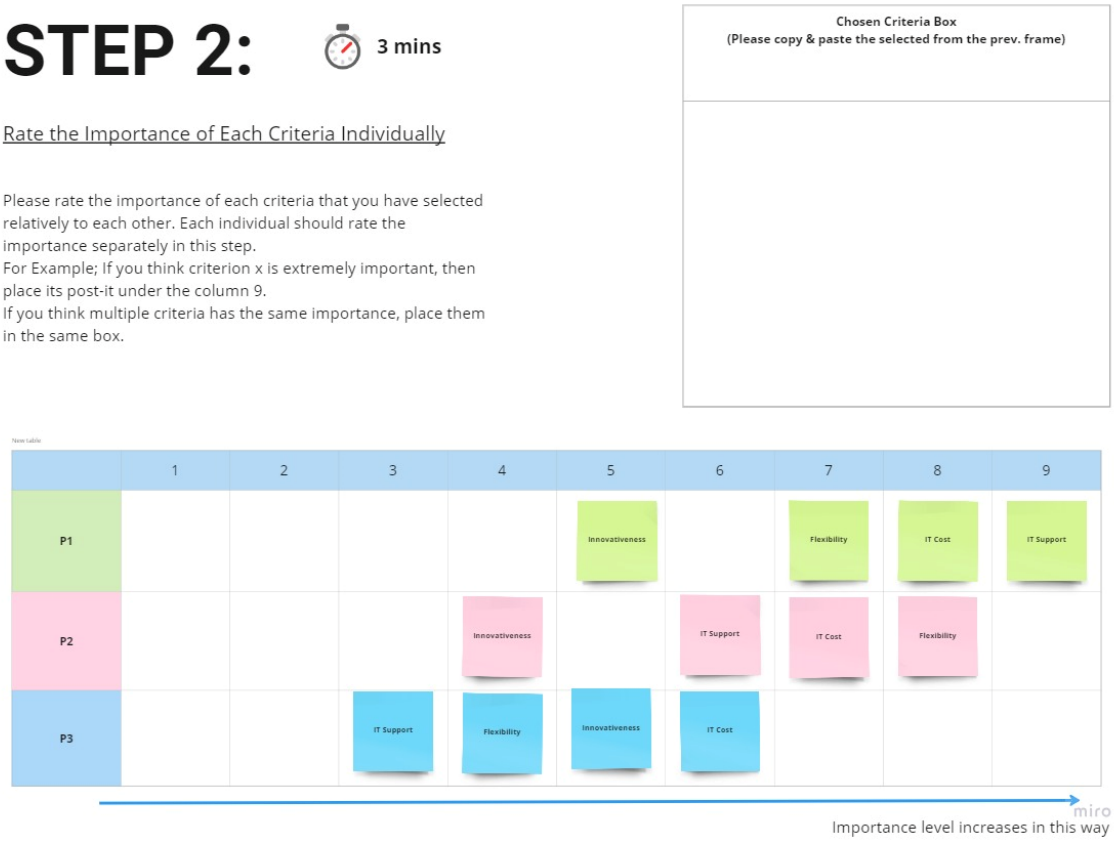


WG-Europe

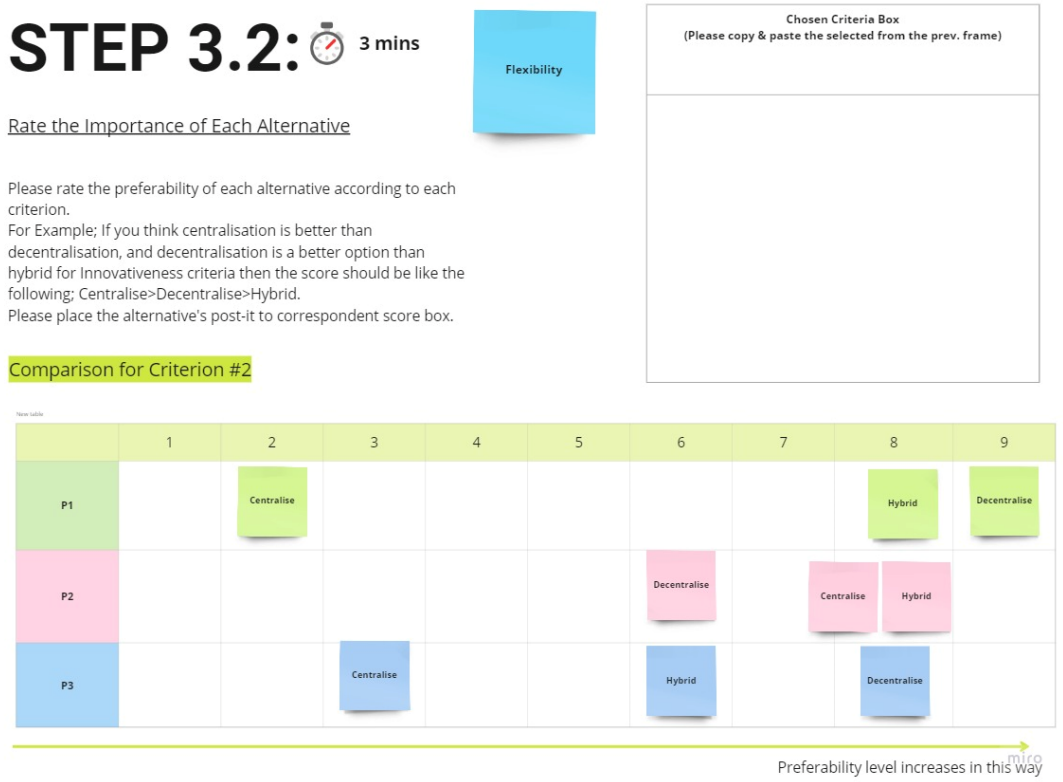
Selected Criteria

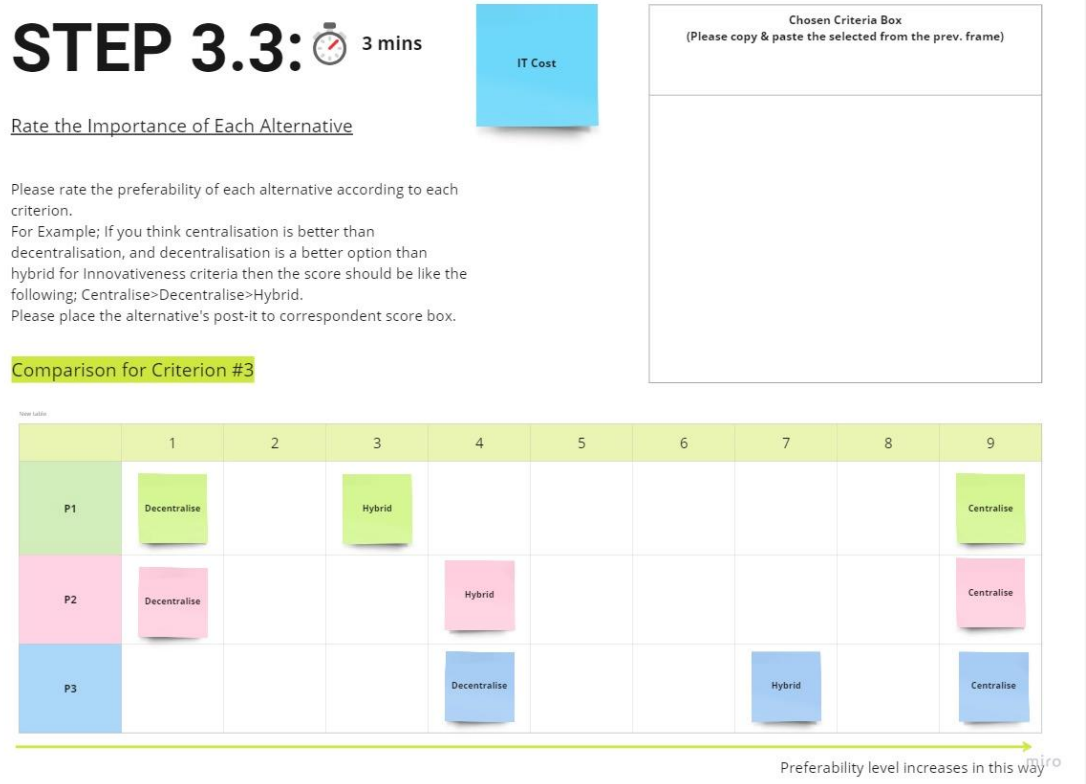


Criteria Weighting



Alternative Weighting for Each Criterion





STEP 3.4: 3 mins

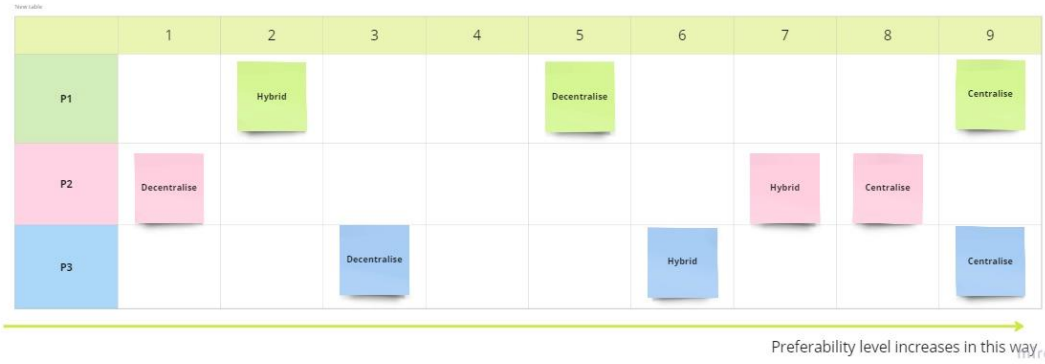
IT Support

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #4



STEP 3.1: 3 mins

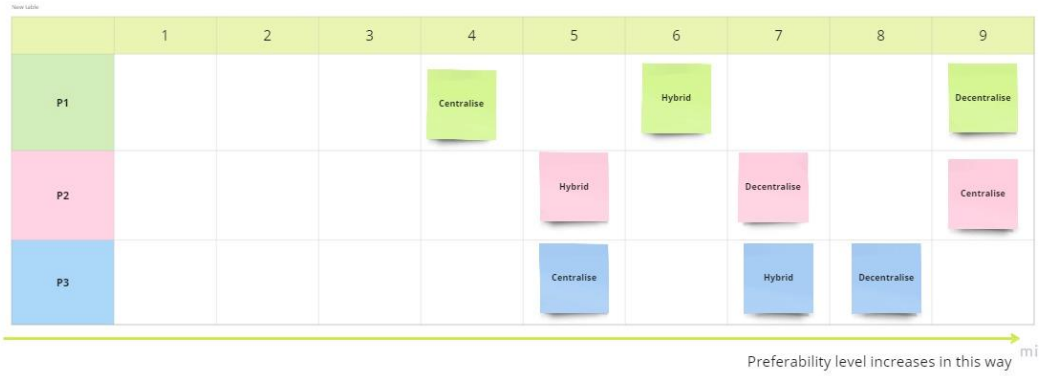
Innovativeness

Chosen Criteria Box
(Please copy & paste the selected from the prev. frame)

Rate the Importance of Each Alternative

Please rate the preferability of each alternative according to each criterion.
For Example; If you think centralisation is better than decentralisation, and decentralisation is a better option than hybrid for Innovativeness criteria then the score should be like the following; Centralise>Decentralise>Hybrid.
Please place the alternative's post-it to correspondent score box.

Comparison for Criterion #1



Appendix C: AHP Calculations of Each Workshop Group

WG-Asia

Selected Criteria

CR1: IT Support

CR2: IT Cost

CR3: Flexibility

CR4: Collaboration Ability

Criteria Weighting

	CR1	CR2	CR3	CR4	Priority Vector
CR1	0,27	0,27	0,27	0,27	**0,27**
CR2	0,33	0,33	0,33	0,33	**0,33**
CR3	0,19	0,19	0,19	0,19	**0,19**
CR4	0,21	0,21	0,21	0,21	**0,21**

Alternative Weighting

	Centralise	Decentralise	Hybrid	Criteria Weights
CR1	0,44	0,24	0,32	0,27
CR2	0,35	0,21	0,44	0,33
CR3	0,33	0,33	0,33	0,19
CR4	0,31	0,43	0,25	0,21

Results

	Centralise	Decentralise	Hybrid
CR1	0,12	0,06	0,09
CR2	0,12	0,07	0,14
CR3	0,06	0,06	0,06
CR4	0,07	0,09	0,05
Total	0,36	0,29	0,35

WG-Australia

Selected Criteria

CR1: IT Cost

CR2: Collaboration Ability

CR3: Innovativeness

CR4: Flexibility

Criteria Weighting

	CR1	CR2	CR3	CR4	Priority Vector
CR1	0,32	0,32	0,32	0,32	**0,32**
CR2	0,28	0,28	0,28	0,28	**0,28**
CR3	0,15	0,15	0,15	0,15	**0,15**
CR4	0,26	0,26	0,26	0,26	**0,26**

Alternative Weighting

	Centralise	Decentralise	Hybrid	Criteria Weights
CR1	0,41	0,07	0,51	0,32
CR2	0,53	0,06	0,41	0,28
CR3	0,20	0,38	0,42	0,15
CR4	0,30	0,40	0,30	0,26

Results

	Centralise	Decentralise	Hybrid
CR1	0,13	0,02	0,16
CR2	0,15	0,02	0,12
CR3	0,03	0,06	0,06
CR4	0,08	0,10	0,08
Total	0,38	0,20	0,42

WG-Latin and North America

Selected Criteria

CR1: Innovativeness

CR2: Flexibility

CR3: IT Support

CR4: Integration Ability

Criteria Weighting

	CR1	CR2	CR3	CR4	Priority Vector
CR1	0,28	0,28	0,28	0,28	**0,28**
CR2	0,23	0,23	0,23	0,23	**0,23**
CR3	0,24	0,24	0,24	0,24	**0,24**
CR4	0,26	0,26	0,26	0,26	**0,26**

Alternative Weighting

	Centralise	Decentralise	Hybrid	Criteria Weights
CR1	0,06	0,39	0,55	0,28
CR2	0,25	0,27	0,48	0,23
CR3	0,57	0,06	0,37	0,24
CR4	0,06	0,58	0,35	0,26

Results

	Centralise	Decentralise	Hybrid
CR1	0,02	0,11	0,15
CR2	0,06	0,06	0,11
CR3	0,13	0,01	0,09
CR4	0,02	0,15	0,09
Total	0,23	0,34	0,44

WG-Europe

Selected Criteria

CR1: Innovativeness

CR2: Flexibility

CR3: IT Cost

CR4: IT Support

Criteria Weighting

	CR1	CR2	CR3	CR4	Priority Vector
CR1	0,20	0,20	0,20	0,20	**0,20**
CR2	0,26	0,26	0,26	0,26	**0,26**
CR3	0,30	0,30	0,30	0,30	**0,30**
CR4	0,24	0,24	0,24	0,24	**0,24**

Alternative Weighting

	Centralise	Decentralise	Hybrid	Criteria Weights
CR1	0,29	0,41	0,30	0,20
CR2	0,20	0,41	0,39	0,26
CR3	0,60	0,11	0,29	0,30
CR4	0,56	0,16	0,28	0,24

Results

	Centralise	Decentralise	Hybrid
CR1	0,06	0,08	0,06
CR2	0,05	0,11	0,10
CR3	0,18	0,03	0,09
CR4	0,13	0,04	0,07
Total	0,42	0,26	0,32