Application of KJ Method in an Aeronautics Collaborative Project

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Abstract

This paper investigates the application of the *Kawakita Jiro (KJ) method* within a collaborative aeronautics project aimed at optimising aircraft development processes. The KJ method, a recognised ideation technique, is used to clarify often ambiguous strategic goals and make them more operational. By involving stakeholders from different aeronautics companies, the method helps to translate high-level goals into actionable terms. The study shows how this participatory business modelling approach improves the structuring of complex information and promotes collaborative problem solving in industrial settings. The results show that the KJ method not only improves the understanding and organisation of strategic objectives, but also enhances collaboration between different stakeholders, thereby contributing to more effective and innovative industrial systems design methodologies in the aerospace sector.

Keywords

KJ method, requirements, goal elicitation, industrial system, Industry 5.0, Industry 4.0, strategic objective

1. Introduction

An organisation's strategy, often referred to as strategic management, defines its very high-level objectives [1, 2]. Strategic management focuses on long-term objectives, initiatives, and the resources needed to achieve them. These strategic objectives are crucial because they help focus efforts on what is most important for an organisation's success. They articulate the desired outcomes that a company or institution aims to achieve over a defined period, typically several years. These objectives serve as a roadmap for the organisation and guide decision-making processes at all levels. By setting strategic objectives, organisations can better navigate their competitive environment and adapt to changing circumstances while staying true to their long-term aspirations. However, strategic goals can be extremely vague. For example, Industry 5.0, which emphasises the reintegration of human intuition and creativity into manufacturing, includes broad strategic objectives such as *resilient provider of prosperity* and *wellbeing of industrial workers* [3].

Such objectives are difficult to translate into concrete targets. Imagine stakeholders trying to design an industrial system. How do you translate a goal such as *resilient provider of prosperity*

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into concrete terms? What does this mean in terms of buildings, assembly line design, choice of tools, etc.? In the context of a project, it can be useful to bring stakeholders together to clarify strategic objectives and make them more concrete. This falls within the scope of *Participatory Enterprise Modelling* [4, 5], where existing methods can be used or adapted. Specifically, as part of a research project, we brought together a group of experts from five different aerospace companies to clarify a strategic objective. The objective is to design an innovative industrial system. We used a well-known participatory enterprise modelling method: *the Kawakita Jiro method* (KJ method) [6].

The *KJ method* named after its creator Jiro Kawakita, is a technique designed to generate and structure a large number of ideas, transforming chaos into an ordered and harmonious system. Developed by the Japanese anthropologist Jiro Kawakita since 1953, this method is particularly useful for categorising extensive collections of ideas, opinions, or qualitative data sourced from diverse inputs. The primary objective of the method is to generate and structure a substantial quantity of ideas to construct an orderly and coherent framework from a state of disorder [7, 8].

The KJ method is particularly effective for organising and analysing large amounts of qualitative data. By grouping similar ideas, it helps to identify underlying patterns and structures, supporting informed decision making. While this method is effective in fostering creativity and consensus, its iterative nature and the format of the final document (an essay) make it less suitable for our time constraints and objectives.

Surprisingly, despite its origins in the 1950s, the KJ method remains under-utilised in the field of *Participatory Enterprise Modelling* (PEM) [4, 5]. In contrast, methods such as creativity workshops [9, 10] are more commonly used in these contexts. However, it appears that the KJ method, with its long history and proven effectiveness over decades, deserves greater attention and application within PEM. Its structured approach to idea generation, categorisation and problem solving fits well with the collaborative nature of PEM, making it a valuable tool for improving communication and decision-making in complex, multi-stakeholder environments.

We applied the KJ method to a theoretical but representative use case aimed at defining a new aerobatic aircraft family, single and twin-seat, with a primary focus on cost minimisation. Three aircraft manufacturers participated in the use case with the aim of fostering collaboration to design the most efficient production system. The exercise aimed to optimise the design process by addressing both functional and economic considerations to ensure that the resulting aircraft would meet the required specifications at the lowest possible cost.

Through this case study, we have explored the application of the KJ method to bridge the gap between abstract strategic goals and their practical implementation, thereby enhancing the overall efficacy of the requirements elicitation process. Through this approach, the study seeks to contribute to the development of more robust and collaborative industrial system design methodologies, ultimately driving innovation and improving performance in the aeronautics sector.

2. Our Approach

2.1. Motivation

The KJ method's collaborative approach to idea generation addresses the need to cater complex industrial objectives. This research aims to contribute to the practical application of the KJ method for clarifying strategic goals. While the potential of the method to foster consensus and understanding is evident, its application in industrial settings presents challenges. Time constraints, the iterative nature of the map grouping phase and the requirement for a final textual document make direct implementation of the traditional KJ method difficult.

2.2. Ideation Method

A summarised outline of the sequence of our collaborative work session is given as follow:

1. *Strategic objective selection*

   A strategic objective is selected from a pre-defined set to be studied during the session.

2. *Ideation stage* (card writing)
   - Distribute blank cards and pens to participants.
   - Participants work individually and write down their thoughts on the cards independently (one single idea per card).

3. *Reading and clustering stage* (card grouping)
   - Model experts collect all cards and mix them.
   - Recover white cards to prevent participants from adding new cards.
   - *Card study*:
     - The facilitator takes a card and reads it out loud.
     - Participants freely discuss the content.
     - The facilitator places the card on the table. Participants can choose where to place the card and whether to combine it with previously placed cards.
   - Participants are allowed to add new ideas on marked cards and repeat the card study process until no new ideas are added.

4. *Generalisation stage* (chart making) :
   - Once the deck is finished, proceed to clustering/grouping.
   - Write names that summary each group on coloured cards.
   - Elicit relationships by drawing arrows between clusters.

5. *Digitisation and data cleansing* (final document) :
   - Create a computerised version of the data using graphical tools.
   - Some information from discussion can be integrated.

Figure 1: Illustration of the session

2.3. Tools and organisation

The workshop took place over a single day, with two dedicated 2-hour sessions scheduled among other meetings. The workshop was held in a room with two tables. The main table was centrally located to facilitate participants' interaction with the cards. A large sheet of paper was provided for direct note taking. To minimise distractions and encourage focused discussion, computers were banned from the main work area. A second table was positioned at the back of the room. Participants had unrestricted access to this area throughout the workshop to complete professional tasks. Figure 1 shows the room layout during the workshop.

Figure 2 shows the tools used during the session: cards (three colours), example cards, pens, pencils, paper to cover the table, summary sheets, sheets to display for the studied objective, scissors and tape.

2.4. Participants

2.4.1. Domain experts

The workshop was attended by twelve people. In addition to representatives from the core aircraft design team from three aircraft manufacturers, experts from collaborating companies were also present. These companies included: a specialise compagny in 3D visualisation; an aircraft

Figure 2: Modelling session tools

components factory; and a systems engineering expertise compagny. The pool of participants included two systems engineers, four*aircraft architects*, four *industrial systems architects* and two *information visualisation specialists*. An aircraft architect is an aerospace engineer who specialises in aircraft design and plays a critical role in the creation and development of new aircraft or the modification of existing aircraft. Aircraft architects expertise in engineering principles, aerodynamics, materials science, propulsion systems, avionics and manufacturing processes enables them to design aircraft that meet specific performance, safety and economic requirements. Industrial Systems Architects are responsible for designing and overseeing the development of complex industrial systems. This role involves the integration of components, processes and technologies to create efficient and effective systems.

2.4.2. Model experts

The model expert team consisted of three researchers. One acted as *facilitator*, while another took on the role of *minute-taker* and *tool operator*, and supporting the facilitator. The third researcher acted as *minute-taker*, focusing on methodological observations. Information presented in Section 3 is derived from his notes; he did not participate in the facilitation of the workshop.

3. Application

In this section we describe how our variation of the *KJ method* was applied and the final idea model obtained. The final ideas model is presented Figure 4.

3.1. Modelling Session Content

Installation and strategic objective selection (Stage 1) *10 minutes*: The session began with a brief overview of the structure of the workshop and the proposed variation of the KJ method (subsection 2.2). Participants were then reminded of the overall workshop and use case objectives. The strategic objective of *producing a low-cost aircraft* was collectively selected to be studied.

Ideation stage (Stage 2) *6 minutes* : In this individual brainstorming phase, domain experts engaged in solitary idea generation. Each participant independently recorded their ideas on a white Bristol card, fostering a focused environment conducive to creative thinking. There was no time limit or maximum number of ideas. The anonymity of the cards was maintained. A total of 51 cards were generated, with two pairs of identical cards resulting in 49 unique ideas. This phase ended when all participants stopped writing and agreed to continue.

Reading and clustering stage (Stage 3) *44 minutes* : All the cards collected were read aloud one by one by the facilitator. Participants were encouraged to clarify any misunderstandings or ask questions. When discussion of an idea was complete, the card was placed on the table. Participants collaboratively grouped the cards based on perceived affinities, with clusters evolving dynamically as new cards were introduced. The physical arrangement of the cards on the table required the active involvement of domain experts. This process continued until all cards had been placed and a consensus on groupings had been reached.

A secondary ideation phase was introduced, resulting in one additional card (*obsolescence*), bringing the total to 52 cards and 50 unique ideas.

Generalisation stage - clustering (Stage 4 part 1) *40 minutes* : For each idea cluster, participants identified the underlying general concept. This involved identifying the main principle, theme or function underlying a specific idea. By abstracting from specific and immediate details, participants are encouraged to explore broader implications and generated a more generalised representation. Practically speaking, when a cluster is created, all the white cards are placed in a pile under the blue card representing the general idea.

Four groups, each containing a single card, required further investigation. The cards *what is the existing industrial system?* and *"cost acquisition" is not an operational objective* were initially excluded as they seemed unrelated to the primary objective, but were later integrated into a new group called*methodological issues.* The card *Make-or-buy policy?* remained a separate cluster, while *Supply chain is risky* and *Obsolescence* were combined into a single group.

Generalisation stage - relationships (Stage 4 part 2) *45 minutes* :
Relationships between clusters of ideas were identified and represented using arrows. Domain experts, guided by the facilitator, selected three primary types of relationships: *conflict*, *cause* and *impact*. These correspond to the original KJ method's relationships of *contradiction*, *connection* and *interdependence* [7]. An additional relationship, *belongs*, was introduced to capture weaker associations observed during the session. This relationship was modelled as a link to the final model in the *Digitisation and data cleansing* stage.

Dependencies between ideas were categorised as either unidirectional or bidirectional. The facilitator used coloured pencils to draw arrows on the table to represent these relationships, once consensus had been reached among the participants.

Final generalisation *10 minutes* : Here a final clustering operation takes place. The aim is to arrive at a small number of ideas, but essential ideas that are strongly linked to the strategic objective. The aim is not to cluster at all costs, but to see if there are any generalisations that deserve to be made in order to make the overall picture easier to understand.

Digitalisation and data cleansing (Stage 5) : The final model was digitised by the *tool operator* a few weeks after the workshop. The digital representation was based on photographs taken during the session and the original physical cards. Graphical elements and relationships were standardised to conform to common visual conventions, such as the use of red to represent conflict. Due to material limitations, this standardisation was not possible during the workshop itself. Two approaches were considered for the terminology used. The first approach was to retain the original French terms without modification in order to preserve the original meaning. The second approach, presented in this paper, involved translating the terms into English. We standardised the wording and used workshop notes to select the most appropriate terms.

One card, *make-or-buy policy*, was split into two separate boxes during the digitisation process : *make policy* and *buy policy*. This decision was based on annotations made on the physical map and is a purely graphical adjustment.

3.2. The Make-or-Buy policy card specific case

The *make-or-buy policy* is a strategic business decision framework for determining whether to produce goods internally (make) or purchase them from external suppliers or vendors (buy). This decision is an integral part of an organisation's supply chain strategy and is subject to ongoing evaluation based on market conditions and internal capabilities. The aim is to optimise resource allocation, reduce costs and improve overall competitiveness.

During the collaborative modelling session, and more specifically during the *Generalisation stage* (Stage 4), it became clear that certain ideas were dependent on a *make* or a *buy* decision. Ideas related to production were aligned with the *make* policy, while those focused on minimising purchased components were relevant to the *buy* policy. This dichotomy between make and buy led the facilitator to adjust the process slightly, that resulted in the separation of the *make-or-buy policy* card into distinct make and buy concepts. This change facilitated the identification of relationships specific to each policy, as shown in Figure 4.

3.3. Final model

The digitalised model obtained at the end of the *Ideation Workshop* is shown in Figure 4; it's the English translation of the original model. The original cards were mainly written in French, with a few expressions in English. None of the participants are native English speakers.

3.3.1. Cards and groups

The final model consists of 52 white boxes representing individual idea cards and 17 blue boxes representing group labels. Some groups have a hierarchical structure. For example, the *project strategy* group is made up of the sub-groups *methodological issues*, *product strategy*, *cost of major components (systems, engines)* and *product just need*, which themselves contain idea cards. Figure 3 shows the final group structure without individual idea cards. It is a digital representation of the physical table arrangement at the end of Stage 4.

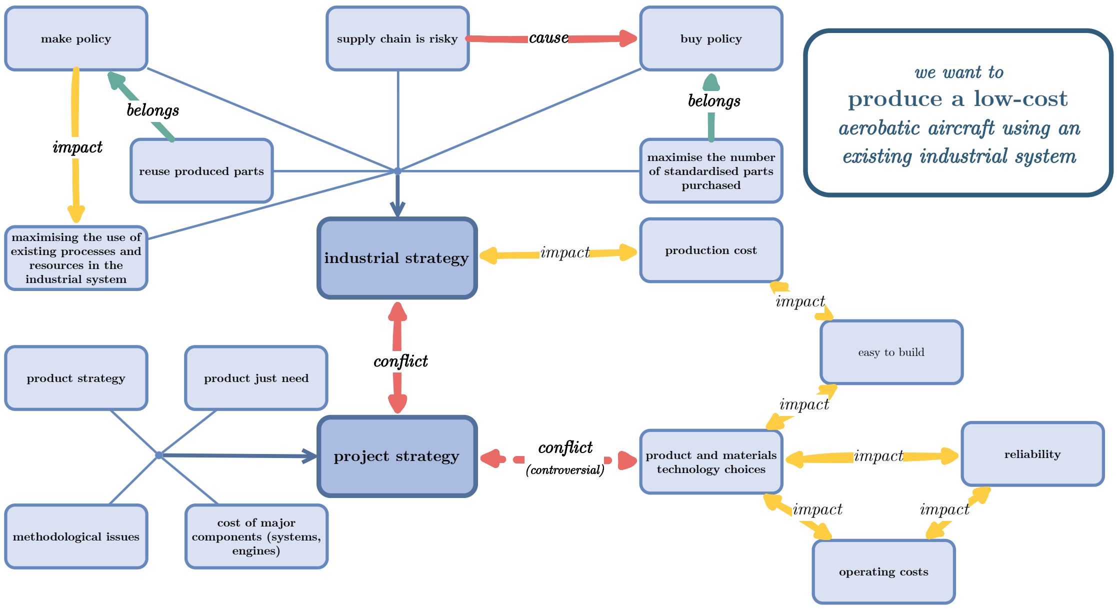

Figure 3: Model of labels

Idea cards can be divided into four categories:

- *strategic objective clarification.* These cards question the terminology or perspective of the strategic objective *produce a low-cost aircraft*. This raises concerns about the costs to be considered. The term *low-cost* may suggest that such an aircraft is not expensive to produce or expensive to use. In terms of production, it may be cheap to build because of the industrial system and its design. Cards in this category are in *production cost*, *operating costs* and *easy to build* clusters
- *ideas that underlie another strategic objective.* Although only one strategic objective was provided, participants naturally linked it to other potential objectives based on their expertise. The *project strategy* cluster encapsulates these ideas.
- *generic ideas.* These ideas need further refinement, such as the concept of *reliability*. Although this generated discussion, the group decided to retain the methodology and avoid further elaboration at this stage.
- *choice-based ideas.* These cards represent choices between potential options, such as the *make-or-buy policy* or *technological choice (materials)* cards.

3.3.2. Relationships

There are four type of relationships in the model : *conflict*, *cause*, *impact* and *belong*. There are two conflict relationships in the model: one between *industrial strategy* and *project strategy* and another between *project strategy* and *product and materials technology choices*. The latter conflict, indicated by a dotted line, was labelled *controversial* due to a lack of consensus among participants as to its validity. A *cause* relationship signifies a causal link between ideas. In the model there is a single cause relationship between *supply chain is risky* and *buy policy* This means that the reason why the *buy policy* is linked to the problem being studied is because of the risky supply chain. The *impact* relationship indicates that decisions related to one idea influence the solution space of another. Importantly, *impact* is distinct from *cause* or *effect*. Given that the workshop was conducted in French, the term (*"influence"*) adopted by participants and the facilitator, most accurately translates to *impact* in English. Finally, the *belongs* relationship is only related to the *make-or-buy* card.

4. Domain experts feedback

Following the modelling session, participants received the final model and were invited to provide feedback via an online survey or email. Most participants expressed satisfaction with the method, highlighting the value of collaborative thinking, knowledge sharing and developing a shared understanding of the use case. The positive response to the ideation session, as evidenced by the subsequent request for a second session focused on a different objective, suggests overall satisfaction with the first attempt.

Feedback from participants highlighted the effectiveness of the method in promoting consensus and shared understanding. As one aircraft architect stated, *"This approach is excellent for converging a group towards a common set of information with a common understanding"*. Similarly, a systems engineer highlighted the value of uncovering different perspectives: *"The opportunity to notice the difference in each person's point of view is enlightening, which is hard to imagine at the beginning"*. Regarding the clustering stage discussions, an industrial systems expert commented: "*The discussions around the clusters helped to better elucidate the themes of the blank cards and sometimes to highlight internal self-censorship"*.

Some participants also add some recommendations, such as the need for relatively short sessions and small numbers of participants to maintain engagement and ensure active participation of all group members.

5. Conclusion

This study investigated the application of the KJ method within a collaborative aeronautic project aimed at optimising aircraft development processes. By integrating the *KJ method* with *Participatory Enterprise Modelling*, we explored its potential to enhance stakeholder involvement and clarify strategic goals. Our findings demonstrate the effectiveness of this combined approach in structuring complex requirements and fostering collaboration between diverse stakeholders.

Future work will focus on developing supporting tools and conducting additional case studies to address the limitations of the method and validate its broader applicability across industries. Building on the promising results of this study, subsequent research will quantify the long-term impact of the KJ method on organisational performance metrics and explore its adaptability to different industry and cultural contexts.

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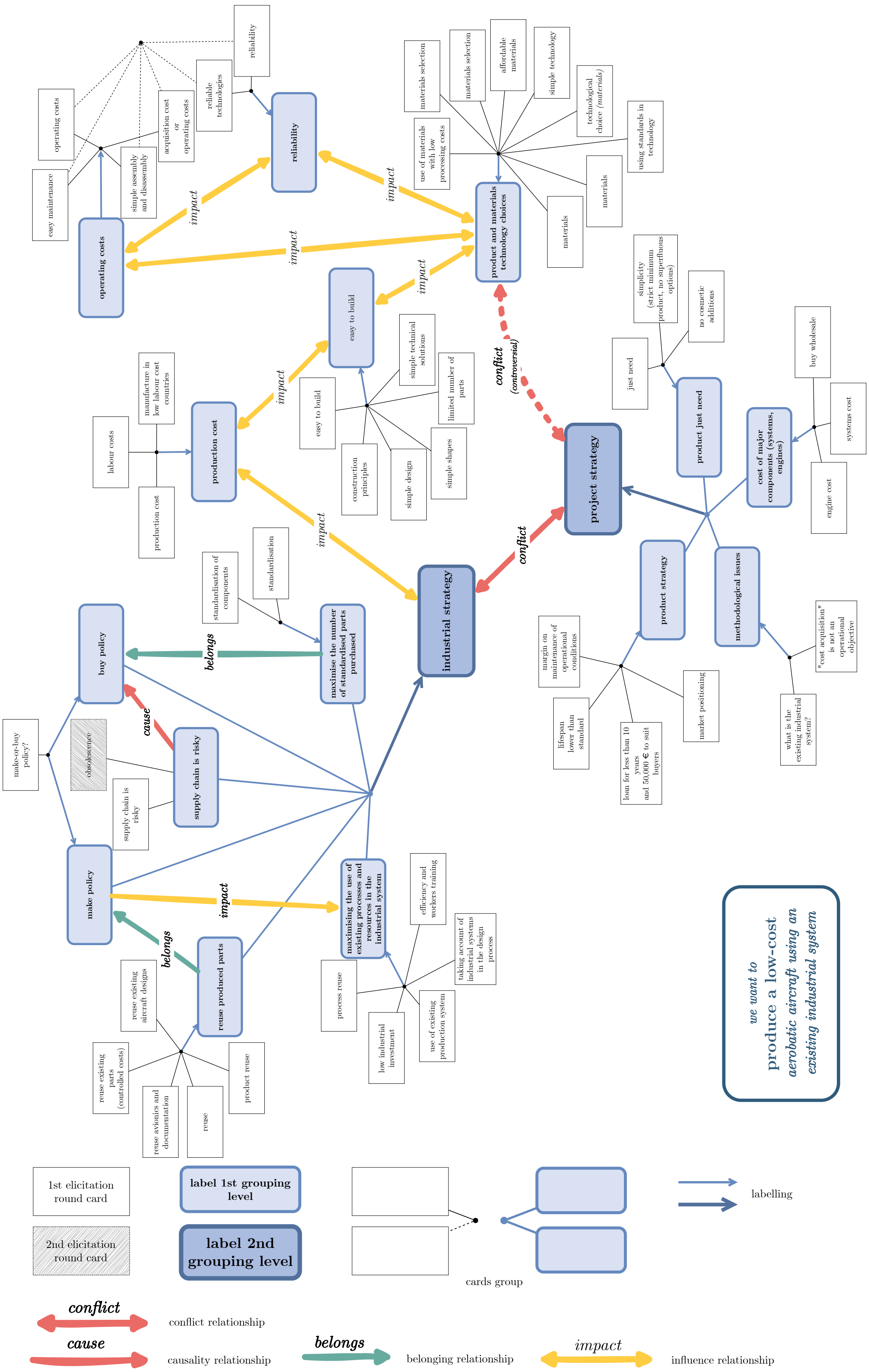

Figure 4: Cards obtained for the problem : *produce a low-cost aircraft*