An Approach for model based Requirement Engineering of Participative Engineering Methodology

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Abstract: In the context of the MAPPER project, the paper presents an approach for model based methodology requirement engineering with the mission of supporting the creation and utilisation of a requirement and assessment model enabling a dynamic representation of all methodology requirement and solution related artefacts and structures. The experiences from the application of the approach are presented and discussed.

1 Introduction

Manufacturing challenges for 2010 include the need for more effective (i.e. faster and cheaper) manufacturing processes that will be carried out inexpensively by collaborative networks of enterprises and quickly adapt to market demands. The CEC funded Strep MAPPER[1] addresses these challenges by focusing on design and manufacturing phases of the product lifecycle. The MAPPER approach [Jo07] is characterized by the following technologies:

Active knowledge models[2] (AKM) of products, processes and other enterprise aspects are used for configuring and coordinating both the human and technical aspects of collaborative design. *Customisable workplaces* give different stakeholders access to the information and services they need for performing their tasks. The *secure collaboration platform* enables enterprises to use each other's engineering tools and product data in a collaborative, yet secure manner, while *participative engineering methodologies* guide joint product and process design, interdisciplinary and inter-organisational collaboration throughout multiple product lifecycles.

[1] Model-based Adaptive Product and Process Engineering: FP6-IST-016527-MAPPER
[2] A visual externalisation of knowledge (*model*) of *enterprise aspects and views* that can be operated on (viewed, analysed, simulated and executed) by authorised users.

An approach for model based requirement engineering of the participative engineering methodologies has been proposed [MA06] and is currently applied in the context of the MAPPER project. Three industrial use case partners representing automotive industries, industrial electronics and automotive supplier industries are the driving force of the project and are the origins for requirements that guide the methodology and technology development in the project. In several cycles, the solutions from the MAPPER solution[3] providers are deployed and used in selected application areas.

This paper presents the core of the methodology requirement engineering approach: The Framework for Methodology Requirement Engineering (FMRE). In section 2 we present the motivation and challenges related to the framework, the FMRE is presented in section 3, followed by a description of one example in applying the FMRE in section 4. The experiences in applying the approach is described and discussed in section 5, and we end the paper with presenting our expectations for the further application of the framework in the continuation of the project in section 6.

In MAPPER, we use the term *methodology* to denote the support for performing activities in the enterprise[4] within the design and manufacturing phases of the product lifecycle for the purpose of achieving the goals for the use case applications, specified by the industrial partners. The baseline methodology developed in the process was provided as a Metis [Troux] process model and an accompanying use guide.

2 Motivation and challenges

The motivation for this framework is the need for a dynamic representation of the use case specific requirements in general, the methodology related use case specific requirements, the combined set of methodology requirements across the use cases, the methodology itself and the assessment of requirement fulfilment by the methodology. All aspects should be linked in a way that ensures documentation and traceability throughout the structure.

A **dynamic representation of the use case specific requirements** is needed to capture the effect on the structures representing the gap between the requirements and the support provided by the MAPPER solutions, both from the evolution of the requirements and from development of the solutions as the project continues.

The challenge related to the simultaneously development of methodology requirements and solutions are rendered in Figure 1 below as a sketch for the life cycle of both requirements and solutions throughout the project. The five rectangles to the left and right represent the layers in the FMRE as described in section 3. The vertical arrows

[3] MAPPER solution is the generic term denoting any provisions to the use cases within methodology, models, workplaces, services, platform and infrastructure from the technical providers in the project.
[4] In MAPPER, the term *enterprise* denotes any kind of enterprise that you – permanently or temporarily – wish to regard as a unit with defined activities, participants and resources, such as an organisational unit, a part of a company or a single company.

denote how the contents within the layers are interconnected. The timeline is at the bottom, with the time for the first iteration on requirement elicitation and specification to the left and the time for the final solution provision in the project to the right.

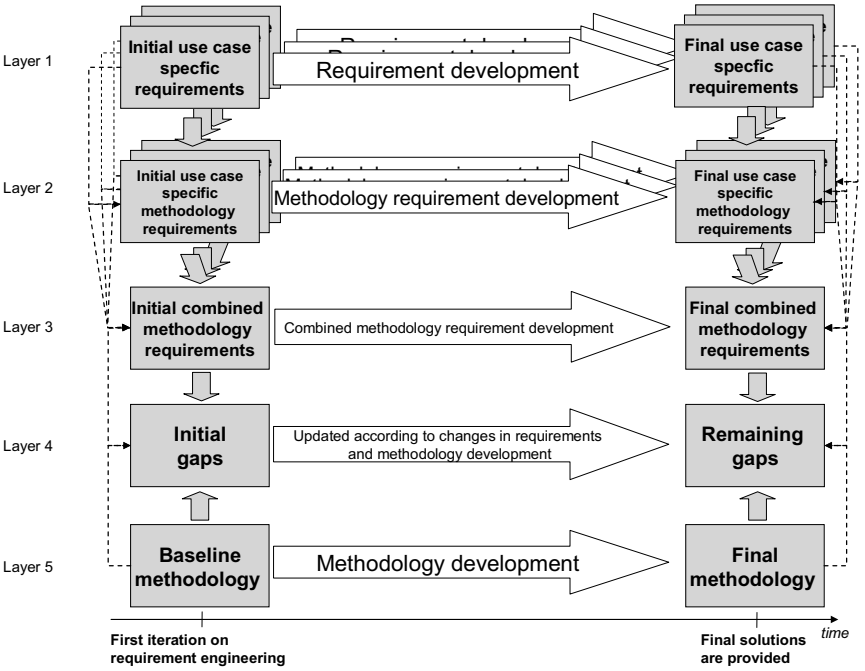

Figure 1: Outline of the life-cycles of methodology requirements and solutions.

As the project moves on, the work on methodology development will proceed guided by the gaps and aiming at filling them. However, the methodology requirements as stated initially will also be object to changes by the use cases as new versions of the MAPPER solutions are deployed and experiences in the pilots are gathered. Hence, the gaps should be updated at any given time as the result of an impact analysis, to reflect the changes at both sides; the evolution of methodology requirements and the methodology improvements respectively.

Between the two emphasised points in time, the use cases and the methodology development teams will collaborate to ensure coordination of the needed flow of results from each party. These are enhanced requirement sets from the users and enhanced methodology components from the methodology development teams.

Based on the life-cycle observation above we can state that: *When the set of remaining gaps is minimised, the objective of the methodology development of providing useful methodology and guidelines to the use cases is met.* When using the term ‘minimise the set of remaining gaps’ instead of ‘empty the set of remaining gaps’, we indicate that the

methodology development cannot guarantee that all requirements are met during the course of the project. There are several reasons for this: the limitation of resources and time in the projects, the nature of the methodology requirements with respect to solution complexity (e.g. organisational, technical), the priority of the methodology requirements etc. Additionally, a successful utilisation of the dynamic representation is depending on the ability of the stakeholders and participants in the processes of requirement engineering and the solution development to update the models according to the actual development taking place. This is a challenge similar to the generic challenge of articulating work performance [Jor04].

By applying the principles given by this framework, we have established *an initial visual Metis model for methodology requirement and solution assessment support*, to be used in the continuation of the project. In the process of establishing this model, the requirement models developed by each of the industrial use case partners as enhanced solution models were used as input. One of the challenges of developing the multidimensional model was **extracting both implicitly and explicitly stated methodology-related requirements** from the initial requirement models provided by the industrial partners. In the initial requirement models the requirements were classified according to the AMPS categories:

- *Approach* requirements, relevant in cases where several alternative approaches exist for an activity in the use case, e.g. line vs. matrix organisation of projects.
- *Methodology* requirements include any requirement related to methodology use and design, e.g. required extensions or refinements of the baseline methodology.
- *Platform* requirements include requirements with respect to the MAPPER infrastructure, additional IT infrastructure in the use case or information resources.
- *Solution*[5] requirements concern implementation characteristics of the solution for a specific project. An example could be which service to use for a specific project when several equivalent services exist.

At first glance, it would be easy to recognise methodology specific requirements among the set of requirements from the use cases, as some of them are explicitly categorised as methodology requirements. However, other requirements might have relevance for methodology as well, although this is not explicitly expressed. New methodology requirements might arise from an in-depth analysis of the original requirements within another category. Stated requirement might differ with respect to level of abstraction and generality. Generally stated requirements might be the source for several more specific requirements of which some could have clear methodology relevance. Sets of specific requirements within various categories might lead to new more general requirements of

[5] The term *Solution* in the context of the AMPS does by definition not match the meaning of the term MAPPER solution used in this paper.

distinct methodology relevance. Hence, all requirements from the use cases were examined for possible methodology relevance. For all methodology requirements identified in such analysis the relationship to the source requirements was explicitly expressed for documentation and traceability reasons.

In the project we are concerned to identify, establish and apply generic solutions of relevance for all use cases, to ensure sharing of experiences and best practices, and let the requirement development be based on experiences of more than one individual use case. This raised another main challenge in establishing the multifold model: The **need for identification of methodology requirements for the use cases in combination**. Whenever methodology requirements from several use cases seemed to be expressing the same needs, we introduced one and only one requirement expressing those needs on behalf of the use cases in question.

Based on the above-mentioned challenges, we can illustrate the space spanned by the initial requirements from the use cases by Figure 2 below.

Figure 2: The space spanned by the source requirements.

3 The Framework for Methodology Requirement Engineering

The FMRE in its current state is organised by a structure of five layers:

1. **The use case specific requirements** organised in one container for each use case. Within each container, all requirements identified in the preceding elicitation requirement process are represented as requirement objects clustered according to the requirement types defined by the AMPS classification.

2. **The use case specific methodology requirements** organised in one container for each use case. Within each container, all requirements identified to have methodology relevance are represented as requirement objects. All requirement objects in this container are related to the requirement objects representing the source belonging to the same use case in layer 1. The methodology requirement

objects are ordered in clusters expressing the typical use case context[6] in which the source requirements originated from.

3. **The combined methodology requirements** are the result of the process of normalisation and combination of the use case specific methodology requirements. That is, when requirements from several use cases seem to express the same needs, they are represented as one requirement object at the combined level. The combined methodology requirement objects are related to the use case specific methodology requirement objects representing the source of the combination process, and they are ordered in clusters corresponding to the clusters at layer 2.

4. **The gap between the requirements and the methodology** is represented by *support* objects and connected relationships. The mission of the support objects is twofold: firstly to express the kind of support required to fulfil one or several requirements, and secondly to express the extent to which this type of support is provided by one or several existing methodology components. In the cases where no such methodology components are present, dedicated *issue* objects are inserted in the methodology model in the context where the methodology components were expected, representing the missing support. Hence, each support object is related to one or more methodology requirement objects in layer 3 on the one hand, and to one or more objects representing methodology components (mainly process objects) or issue objects in layer 5 on the other. The extent to which the support is provided is represented by the fulfilment property of support objects, by values *full*, *partly* and *none*.

5. **The existing methodology** is represented as a Metis model, using the Metis Enterprise Architecture Framework template, structured according to the POP* dimensions [Athena] into five parts: Goals, Products, Organisation, Processes and Infrastructure / Resources. In the current version of the methodology (the baseline), the process part represents the core of the methodology, divided into four sub-methodologies:

    a. Networked manufacturing enterprise modelling,

    b. Formation and operation of sustainable collaboration,

    c. Multi-project portfolio management, and

    d. Inter-organisational learning.

In Figure 3 below, the conceptual structure of the framework is outlined, showing the object types representing the components within each layer and the relationships representing the links across the layers.

[6] Examples of use case contexts identified: Resource management, Information and knowledge management, and Collaboration between separate units.

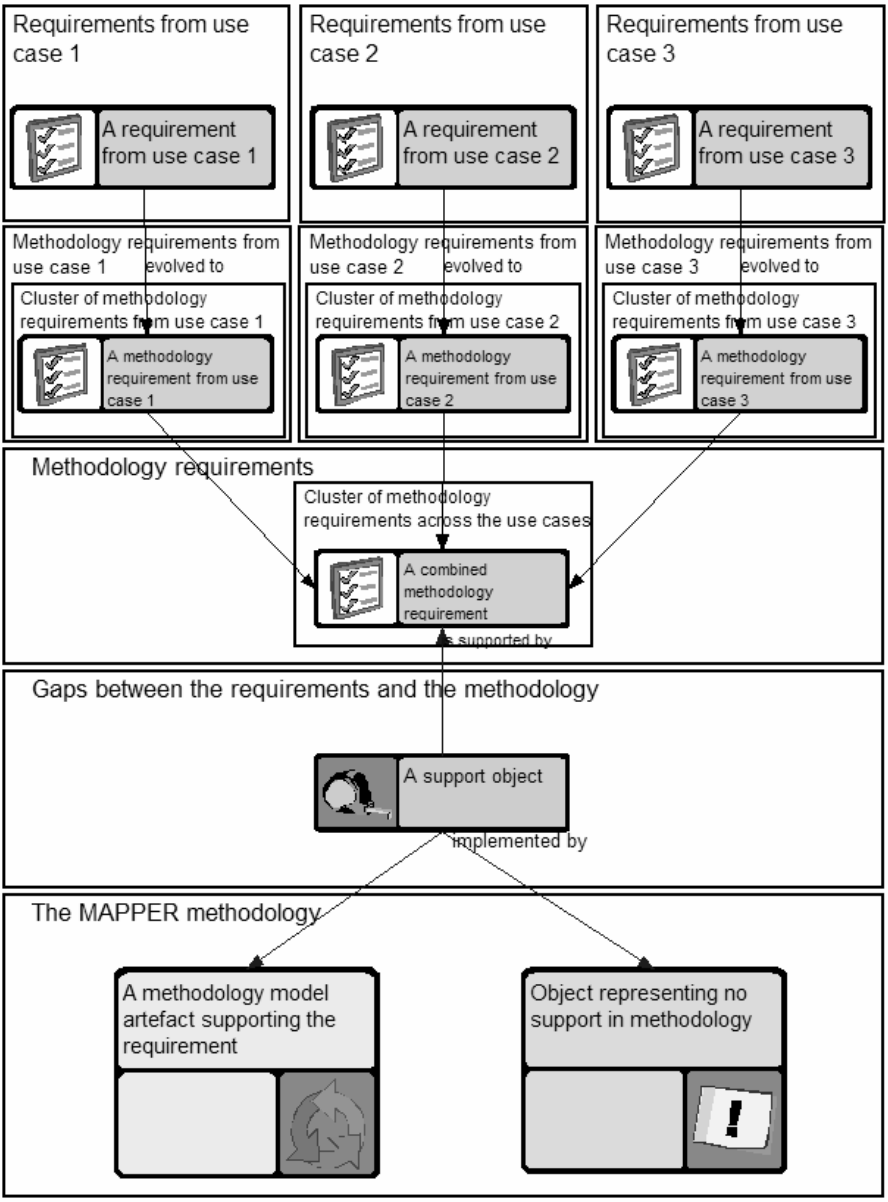

Figure 3: The conceptual structure of the Framework for Methodology Requirement Engineering.

4 Creating the initial Methodology Requirement and Assessment Model by Applying the FRME

The process of establishing the initial methodology requirement and assessment model within in the framework is rendered in the figure below.

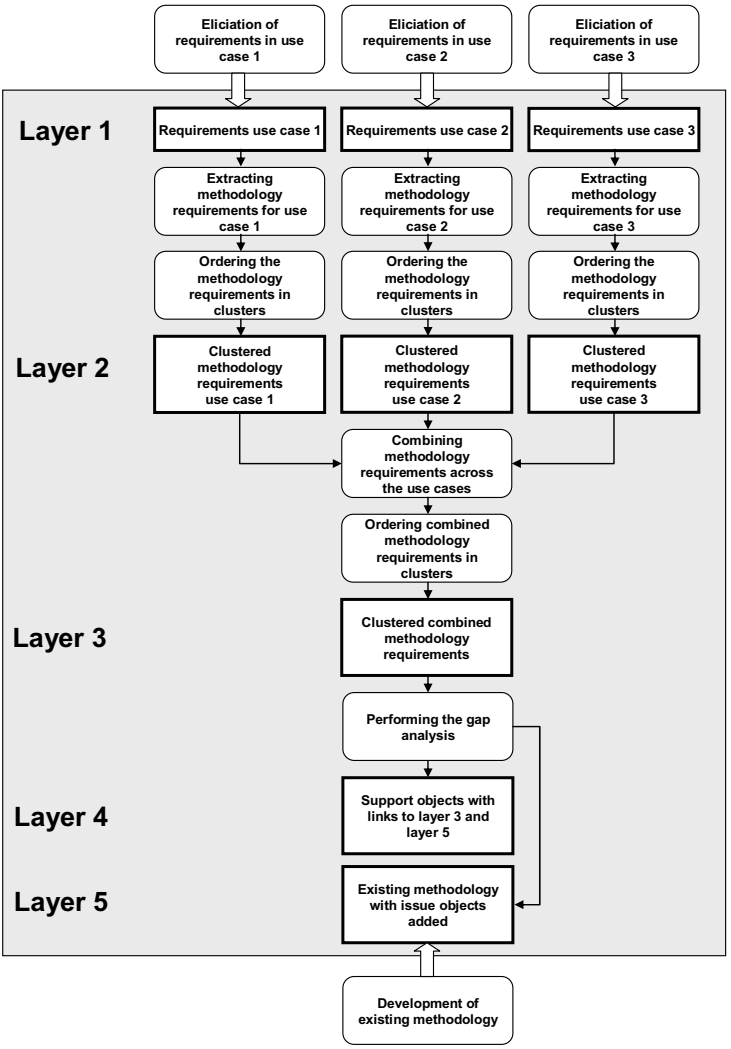

Figure 4: Rendering of the process of establishing the model of methodology requirements and assessment in the FMRE.

The rounded rectangles represent process steps with input and output flows as the connected arrows. The rectangles in bold represents the model parts (i.e. work products) resulting from the steps with the corresponding FMRE layer indicated to the left. The inputs to the process are at the one hand the elicited use case requirements and on the other hand the existing methodology model. The scope of the process is indicated with the grey rectangle.

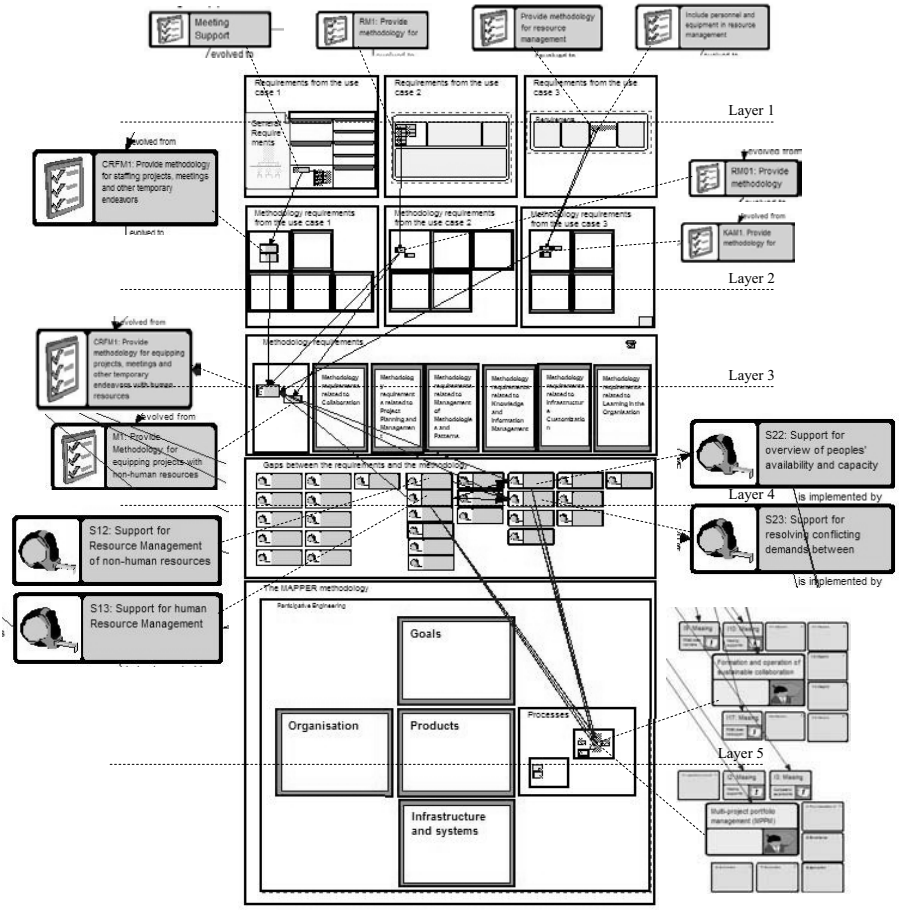

Figure 5: Examples from the multifold methodology requirement and assessment model..

In Figure 5 we illustrate an example from the resulting multifold requirement and assessment model, showing how the issue on 'resource management' is involving all use cases with their slightly different requirements: for use case 1 it is about supporting meetings, for use case 3 it is about including personnel and equipment in resource management.

Extracting methodology requirements from these use case specific general requirements resulted in three different requirements on layer 2, which we clustered into two different methodology requirements on layer 3: 'Provide methodology for equipping projects, meetings and other temporary endeavours with human resources' and 'Provide methodology for equipping projects with non-human resources'.

To bridge the methodology requirement and the MAPPER methodology, we created *Support* objects on layer 4 like 'Support for resource management of non-human resources', 'Support for human resource management', 'Support for overview of people's availability and capacity' and 'Support for resolving conflicting demands between projects' Each support object was then related to the corresponding methodology requirement objects at layer 3, and to objects in the MAPPER methodology representing the requested support.

However, when searching for required support in the existing MAPPER methodology, we concluded that a sufficient support related to the 'resource management' issue was missing. Hence, we inserted *Issue* objects in the appropriate context in layer 5 indicating lack of support in the current methodology.

5 Experiences and lessons learned

From the gained experience by applying the approach and the FMRE, we see the following main challenges and lessons learned:

- The concept of methodology in an applicative context seems to be difficult to describe, both in terms of methodology requirements specification, and in terms of methodology solution description. Possible reasons could be:
    - The interpretation of the concept of methodology might vary among the requirement stakeholders.
    - The lack of prototyping and mock-ups in the described approach.
    - Methodology requirement requires close relationships to a description of a possible solution.
    - The close dependency to other kinds of solutions (e.g. services provided by specific tools) requires a multifold view on the combined set of solutions across the solution kinds. Without such multidimensional view, envisioning the nature of a methodology solution might be difficult as descriptions of the corresponding tool provided services are missing.
- Understanding the meaning of the requirements as expressed in the use cases (great variation in levels of abstraction and methodology scope; some inconsistencies).

- Identifying the appropriate criteria for defining the requirements ordering (the clusters), both on the use case specific level and on the integrated level.

- In the Gap analysis: Seeing the relevance of the individual requirements to the different methodology components (i.e. identifying the right distribution of responsibilities for implementing according to the requirements among the methodology component).

- Another aspect of the Gap analysis: Mapping generic methodology requirements on the generic baseline methodology has been difficult, using more specific concrete examples of the use case pilots would have helped (but would have also required more user participation). Therefore, the gap analysis was also difficult to carry out (i.e. the extent to which a requirement is fulfilled was difficult to judge). We expect this to improve with feedback from use case representatives in the next stages of the requirement engineering process.

- Defining the right model primitives to use in the modelling. Based on the main structuring approach provided by the FMRE, the conceptual meta-model has evolved during the work. The decisions on mapping from the conceptual meta-level to the concrete model primitives available in the modelling environment have been the subject to several iterations as experiences are gained.

6 Conclusions and further work

In this paper we presented an approach for model based methodology requirements engineering and solution assessment, including the FMRE. It considers not only requirements to methodology, it shows the gap between the requirements and the existing methodology by means of support objects. The idea of using such a framework in a research project is to be able to address requirements of all users in one model as well as to create and utilise a multifold requirement and assessment model. The additional idea is to use the framework to organise and communicate the work around methodology requirements engineering within the project group.

We have experienced that the structure of the support objects (layer 4 in the FMRE) with the related methodology requirements and the related methodology components is a suitable base for exploration and validation of the current assessment results, for planning of the continued methodology requirement engineering process and of the continued methodology development process. To achieve this, we have recognised the following aspects to take into consideration for the future work:

- Support for validation of the results of the methodology requirements analysis, include the methodology requirements resulting from the complementing eliciting techniques applied in the project (such as ethnographic observations).

- Support for prioritising the support objects.

- Support for versioning control.

- Extension of the application scope of the described approach to other types of requirements, e.g. service requirement engineering and service solution assessment.

- Support for establishing and maintenance of relationships linking objects in the FMRE layers to corresponding objects in similar models for other requirement types, e.g. service requirement and solutions assessment.

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