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A COMPREHENSIVE VIEW ON BENEFITS FROM PRODUCT MODULARIZATION

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1. Introduction

In many cases the phenomenon of product modularization is presented in an inherently positive way. Based on the frequency of these positive cases it might be expected that product modularization is a universal cure for any competitive weaknesses experienced by manufacturing or service companies. Definitely, the many various aspects of product modularization have demonstrated substantial potentials regarding improved and enhanced competitiveness, but our empirical studies illustrate that the efforts in regards to realizing specific product modularization benefits need to be managed carefully.

Our studies illustrates that the expected and the realized benefits from a product modularization effort rarely match. In most cases the companies have only weak estimations about both the type and the magnitude of the potential benefits when planning the modularization project. This indicates a serious need for tools and methods to support companies in being more specific about the expected benefits. Furthermore, this indicates a need for more precise perceptions of the challenges of managing product modularization efforts.

This paper deals with three challenges according to the outset as described initially. First, we will unfold a company neutral empirical based way of how to understand and manage product modularization. Secondly, we will classify and conceptualize the various product modularization benefits. Thirdly, we will evaluate a number of individual industrial product modularization cases according to the conceptualized model of benefits.

The reported study is mainly a qualitative study. In the implication part of the paper we will discuss how the study can be developed further to incorporate enough company cases to generate more substantial insights.

2. Methodology

This study is an introductory study that will be followed by a more thorough structured large-scale study. Therefore, the study has been organized as open-ended interviews studies with the purpose to generate initial insight and to investigate how the discovered phenomena can be researched further in a large-scale study [Eisenhardt, 1989]. Also, this study builds only on Nordic European Companies. Comparable studies will be made in South East Asia for the next empirical round.

The overall research question has been:

How has companies succeeded in realizing benefits from product modularization

The case-studies have followed the same structure:

1. Initial identification of company and prime contact person
2. First visit focusing on demonstration of product (or service). Discussions on modular features of the product. Discussions on definition of modularity and inspirations from other companies. Initial discussions on potential benefits.

3. Analyses of interviews and supplementing materials. Followed up with shorter supplementing telephone interviews.
4. Second visit focusing on impact in other organizational units. Interviews in these parallel organizational units with focus on their perception of the modularization features and their impact on the performance of the respective organizational units. First attempt to quantify modularization impact.
5. Further analyses and supplementing shorter telephone interviews.
6. Third visit with the purpose to present a comprehensive result of the initial analyses. The companies will be represented by participants from more than one organizational unit. These meetings will most often give input to further analyses that will benefit both the research study and the participating company. After the third meeting a formal conclusion will be made.
7. If specific continuing cases have been identified the case study will continue as a long term study with frequent visits.

As a consequence of the chosen methodology some of the cases are still on-going.

3. Modularity in products and supply chains

Initially we found that companies have individual and rather different perceptions of modularization. Even within the same company different definitions and perception most often co-exist. The reason for this is that the experiences have been derived from specific product examples and in the same company different products often generate very different experiences. Some employees have good or bad experiences from prior companies and they bring these experiences with them and mix them with new insights.

Taking outset in this empirically experienced fact we have taken outset in a broad definition of a module by Baldwin and Clark [Baldwin and Clark, 2000]: *A module is a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units. Clearly there are degrees of connections, thus there are graduations of modularity.*

This definition captures the essence of product modularity by specifically addressing the module boundary and the associated interfaces. Within the module there is generally high complexity that requires specific technology knowledge and the weaker connection between modules are established through intentionally designed interfaces.

The power of the module consequently lies both within the module and in the strength of the interfaces. Due to dynamic changes in the surroundings changes will occur both within the modules and in the interfaces. However, in general the interfaces should be more stable over time.

Furthermore, modularity is a relative phenomenon. Nearly all products can be characterized as modular products. The practical interest lies in the relative degree of modularity. Product can as easily be over-modualized as under-modualized. The core of the modularization management task is the find the best relative degree of modularization.

The definition by Baldwin and Clark applies a strictly product perspective. However, the same principles can be applied on a supply chain [Fine, et. al, 2005]. This is of particular interest when discussing benefits of product modularization.

Empirical examples describe how thoroughly designed modular products and thoroughly designed modular supply chains can co-exist and generate superior benefits [Lau et. al., 2007]. The examples show that the benefits from product modularity often are found and realized in the supply chain. This has led Fine to propose a 3D Concurrent Product Development Model that specifically addresses the aspects of co-existing modularity in both product and supply chains [Fine et. al., 2005]. Fine concludes that since the benefits from operating with a modular supply chain often is the most interesting from an overall financial perspective these benefits can only be realized by creating a modular product structure.

Sanchez has conceptualized this in a simple graphical model that illustrates the product and supply chain elements that have to be addressed in order to realize the intended benefits [Sanchez, 2000].

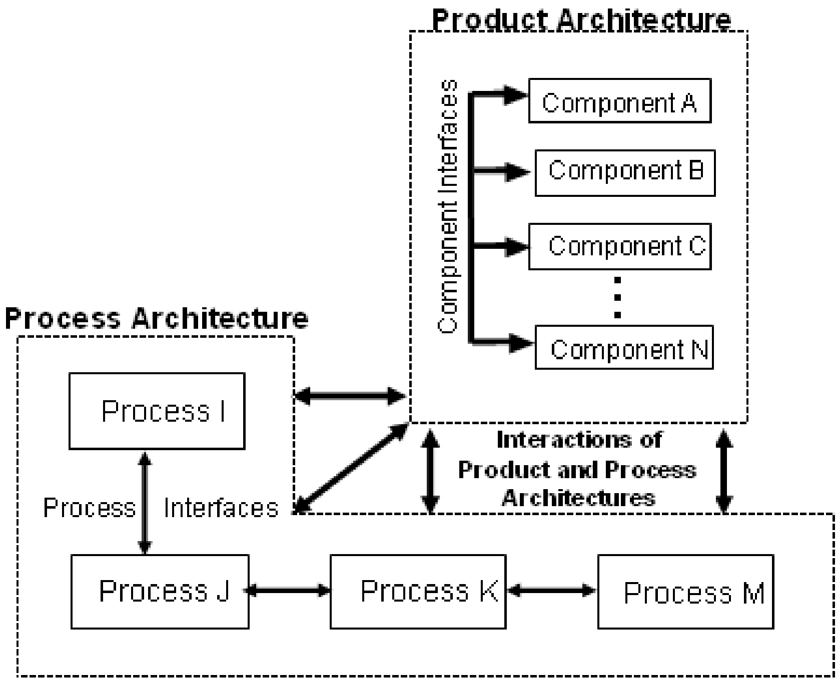

Figure 1. Co-existing modular product and modular supply chain structures [Sanchez, 2000]

3.1 Modularity and Platform

Modularity, product architecture, supply chain architecture, product platform, supply chain platform are terms that often co-exist both in practical industrial settings and in research. In research the terms are normally well defined within individual research communities. The terms are though ambiguously defined when comparing the global research community.

In industry the terms are often used without precise definition and often synonymous. Different organizational units within the same company use different definitions. The definitions are mostly based on specific industrial reference cases, e.g. Volkswagen or LEGO. In both cases companies are referring to these companies as being able to create a variety of products based on a relatively large degree of re-use.

During the empirical case studies we have consequently included experiences from both Volkswagen and LEGO in our discussions with the companies. The LEGO case clarifies that the modularity is associated with the physical building blocks and that well-defined interfaces are crucial in the design of modular products. The replicants in the companies find it relatively easy to transfer this to their own products.

When presenting the so-called A-platform from Volkswagen we challenge the companies to identify the platform (see Figure 2). Clearly the visual representation of the A-platform illustrates the re-use of approximately 60% of all components across the different car brands: VW, Skoda, Audi, and Seat. However, the discussions generally end with concluding that the Volkswagen A-platform should not be defined as a platform. It is rather a simple visual representation of a number of structural subsystems. Furthermore, there is missing some of the most important issues: the associated supply chain systems and their interfaces to the product subsystems. These subsystems and their interfaces are an important part of the explanation for the specific physical form, and most important, are the reason why Volkswagen can realize benefits in both product development and supply chains.

The platform hence becomes an overall slightly abstract phenomenon that incorporates different types of sub-systems. We have chosen to use the term architecture for such sub-systems. These architectures can be more or less modular.

The benefits are realized in a complex interaction between a number of multidisciplinary architectures. To develop and configure these architectures and their interaction is, in short, the management challenge of working with platforms.

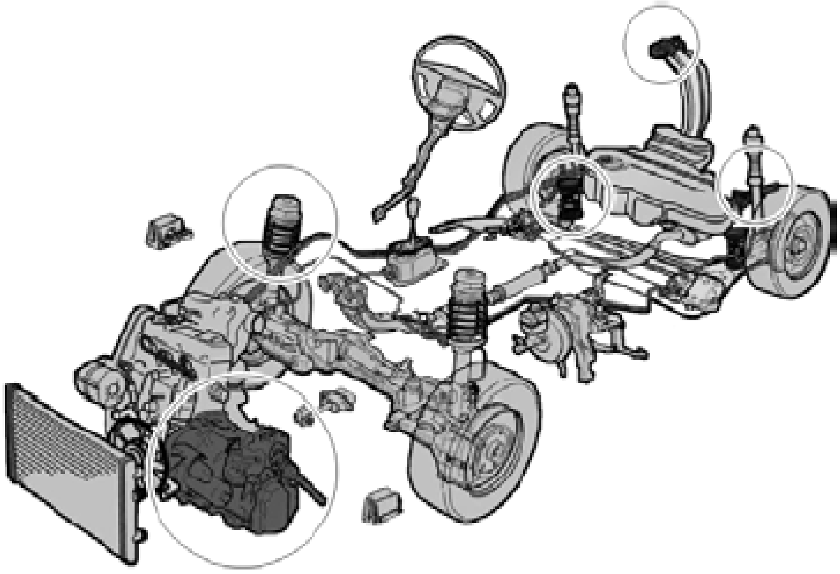

Figure 2. The A-platform from Volkswagen

Due to differences in market dynamics and technologies platforms will be different from company to company. Consequently, there is a need to provide a rich and comprehensive view of platform options to support the company specific work with platforms. We have chosen to name this a platform template in order to emphasize that the realization of a platform challenge is to be considered as a company individual task [Hsuan, et.al., 2007]. Based on the literature review and our on-going empirical research, the following factors have been identified as essential elements to define a platform template:

- The platform is based on one or more architectures that in corporation defines a meaningful part of a product
- The architectures can be product architectures as well as supply chain architectures
- The architectures specifies internal interfaces within an architecture and external interfaces between architectures
- The architectures can be partly modular
- The platform includes relevant knowledge at the architectural level
- The platform serves as a basis for long-term development work
- The platform serves as a basis for short- and medium-term continuous improvement
- Managing the platform includes being specific about how to realize benefits

These elements of the platform template have been widely accepted and recognized by the case companies. The elements have guided as a structure for phase 6 in the research methodology when reporting the findings to the companies. Also, the elements have supported in defining the challenges in the cases that have developed into long-term case studies and research collaboration.

One important element in working with platforms is however not covered by the template. That is the organizational processes including the management efforts. Companies find these managerial issues to be the most difficult cope with. As articulated by Robertson & Ulrich, "Good platform decisions requires making complex trade-offs in different business areas. Top management should play a strong role in the platform process for three reasons: (1) platform decisions are among the most important a company makes, (2) platform decisions may cut across several product lines or divisional boundaries, and (3) platform decisions frequently require the resolution of cross-functional conflict." [Robertson and Ulrich, 1998].

As explained by Meyer & Dalal, platform management is "the integration of the building blocks (the core technologies and processes) with common architectures (the shared subsystems and interfaces), with user requirements aggregated into target market segments towards the end of producing value rich products and systems [Meyer and Dalal, 2002].

In this paper we have chosen to focus on only one of the challenging managerial areas. This is the question of how to specify benefits in terms balancing the platform efforts with the financial benefits. As many potential benefits are not strictly financial and since this type of benefits often prove to be the most important the management challenge becomes rather complex.

Based on our empirical findings we will for the purpose of this paper use the terms platform, architectures and modularization synonymously. It is definitely relevant to develop a more precise vocabulary, but for the purpose of this paper the terms are mixed when applied in industry and we have chosen not to make any effort to create a uniform application of the terms.

4. Benefits of modularization

There are several reasons why companies pursue a product modularization strategy. Some of the benefits of product modularization include reduction of fixed costs of developing individual product variants, greater degree of components and subsystems reuse, increased responsiveness, offer higher product variety to customers, reduction of development lead time, and improved customer service.

The empirical case studies have given specific input to a variety of areas where expected and unexpected benefits have been realized. Among the empirical observations are:

- Product modularity reduces costs in the product life cycle due to the possibilities of economy of scale in production
- Product modularity reduces delivery time due to the possibilities of postponement in supply chain
- Product modularity enhances speed in the product development process due to the possibilities for distribution of activities
- Product modularity enhances speed in the product development process due to well-known structures in the product development project management
- Product modularity enhances speed in the introduction of new product variants due to the reuse of components and structures
- Product modularity enhances the variety due to the flexibility in configuration of the final product
- Product modularity enhances organizational flexibility due to the ease in communication of the product structure
- Product modularity enhances organizational learning due to the inherent structure for accumulation of knowledge

Some of these benefits can be measured by strict financial methods but most of them incorporate types of benefits that either stretch over a period of time or are rather difficult to transfer to financial terms. How increased speed in product launches should for example be measured in financial terms? Intuitively there is a financial benefit but this benefit will occur in future financial years and it is at the point of decision a highly potential benefit. On the other hand the investments in modular products are normally significantly higher than investments in more integrated products.

Based on the empirical findings we have categorized the benefits in six major benefit driver categories and 3 major benefit categories.

The six benefit drivers can be further divided into Research & Development and Manufacturing & Logistics.

Research & Development benefit drivers:

- Carry over. The benefits derived from carry over or re-use of components across more products.
- Technical update. The benefits derived from the ability to upgrade the product technically without changing the product architecture.
- Customization and styling. The benefits derived from the ability to customize or style the product without changing the product architecture.

Manufacturing & Logistics benefit drivers:

- Processes and organization. The benefits derived from having an existing manufacturing process set-up and an organization that can produce the product.

- Supplier availability. The benefits derived from having known suppliers available that can produce needed components at a specific quality level.
- Gradual completion. The benefits derived from being able to produce the product in steps and only specifying the specific product features at a late stage in the production.

Benefit categories:

- Cost, quality, complexity. These benefits will be measured in direct cost.
- Capital binding. These capital binding will occur as intermediate stocks, finished stocks, machines, tools, moulds, etc.
- Lead time reductions. Lead time reduction will occur as reductions on product development lead times, production lead times, logistic lead times, ect.

The benefit drivers and the benefits can be combined in a matrix structure (see table 1).

Table 1. Modularization Benefit Matrix

	Cost, Quality, complexity	Capital binding	Lead time reductions
Research & Development - Carry over - Technical update - Customization and styling			
Manufacturing & Logistics - Processes and organization - Supplier availability - Gradual completion			

The Modularization Benefit Matrix has emerged during the empirical research period. As the matrix finally found the form as shown in table 1 it had a significant impact on the quality of the benefit discussions. In most cases we were able to depict both the initial expectations, intermediate realized benefits, the current state of benefits realized, and finally to discuss expected future benefits.

In the following part we will illustrate the specific application of the modularization benefit matrix based on our empirical research.

5. Discussion and implications

The initial study has incorporated 40 industrial modularization cases. Many companies have provided more than one case and the total number of participating companies is 22.

The case studies have been initiated as qualitative cases focusing at first on the underlying modularization thinking that have been applied during the development of the specific product. In most cases this understanding has been individually perceived by only a few people – in general the project manager. These discussions led us to formulate the "Platform Template" as reported in section 3.1.

During the next phases (phase 4-6 as described in the methodology section 2) we initiated started the analyses of the expected and realized modularization benefits. This approach proved beneficial from a practical company perspective and rather problematic from a research perspective. In general the benefit expectations were mostly one-dimensional. That means, that most cases emphasized one particular goal as the benefit goal. Other benefits were only addressed loosely in mostly qualitative terms. However, as the discussion involved other organizational units and in a time perspective a number of different benefits emerged. This enriched the discussions but made it significantly more difficult to track the original expectations. To overcome these difficulties we have chosen to report the findings as they were agreed on the last formal status meeting (phase 6 in the methodology). Also the projects are not finally evaluated until 2 to 3 years after the launch.

The following table 2 captures a short description of 5 of the 40 cases. These 5 cases represent different companies.

Table 2. Short description of 5 out of 40 modularization cases. The following appreviations applies: B2B: Business to Business; B2C: Business to Consumer; R&D: Research & Development; M&L: Manufacturing & Logistics; L: Low; M: Medium; H: High

Case	Short description	Benefits on direct costs	Benefits on capital binding	Benefits on lead-times
A	The company is in a B2C market in the electronic industry. The case is a launch of a new product in the low-end price market. The degree of newness is considered medium.	R&D: No expected benefits No realized benefits M&L: Expected benefits (M) No realized benefits	R&D: Expected benefits (H) Realized benefits (H) M&L: No expected benefits Realized benefits (H)	R&D: Expected benefits (M) Realized benefits (M) M&L: No expected benefits Realized benefits (H)
B	The company is in a B2B market in the graphical industry. The product is a launch of a multi-customer-product. The degree of newness is considered high.	R&D: No expected benefits No realized benefits M&L: Expected benefits (H) No realized benefits	R&D: Expected benefits (H) Realized benefits (H) M&L: Expected benefits (M) Realized benefits (M)	R&D: Expected benefits (H) Realized benefits (L) M&L: Expected benefits (H) Realized benefits (L)
C	The company is in a B2C market in the consumer goods industry. The project is a technology project that supports numerous customer products. The degree of newness is considered high.	R&D: Expected benefits (H) Realized benefits (L) M&L: Expected benefits (H) No realized benefits	R&D: Expected benefits (H) Realized benefits (H) M&L: Expected benefits (H) Realized benefits (L)	R&D: Expected benefits (H) No realized benefits M&L: Expected benefits (H) No realized benefits
D	The company is in a B2B market in the electronic industry. The product is a new and highly configurable product. The degree of newness is considered high.	R&D: No expected benefits No realized benefits M&L: Expected benefits (H) No realized benefits	R&D: No expected benefits No realized benefits M&L: Expected benefits (H) Realized benefits (L)	R&D: No expected benefits No realized benefits M&L: Expected benefits (H) Realized benefits (M)
E	The company is in a B2B market in the electrical industry. The product is a module that can be configured to a wide range of purposes. The degree of newness is considered high.	R&D: Expected benefits (M) No realized benefits M&L: Expected benefits (H) No realized benefits	R&D: Expected benefits (H) No realized benefits M&L: Expected benefits (H) No realized benefits	R&D: Expected benefits (L) No realized benefits M&L: Expected benefits (H) No realized benefits

In the following we will discuss each of cost benefit categories.

5.1 Modularization benefits on direct costs

In each of the five cases there were substantial expectations to the direct cost benefits. However, the expectations were not realized to the level of expectations in any of the cases. The reactions to the missing benefits were very different.

In Case D and Case E the projects had been approved based on the expected direct cost benefits. In both companies the project managers of the project were eventually fired due to the missing results. Both Case D and E are exemplary from a technical modularization viewpoint.

In Case E the developed module had between 50 and 95% less internal wires, screws, and components compared to the former solution. The problems occurred because the components could not meet the tolerance requirements. As a consequence of this the automated assembly solution performed much below expectations and the product cost increased.

In Case D the markets changed and required a more flexible product portfolio. The assembly solution could not respond to this change in flexibility and the product cost increased.

In Case C the project were sponsored by the CEO. After recognizing the pure results it was decided to make a thorough review of the whole project. This project finished after the three year limit set by the research project but managed to change the performance in a positive direction.

In Case A and Case B the missing direct cost benefits were noted. However, in both cases the projects were initiated as relative small scale projects and positive learning benefits were also considered. Also, in both cases the supplementing benefits performed close to or above the expectations.

5.2 Modularization benefits on capital binding

The discussions on capital binding benefits regarding Manufacturing & Logistics proved to be rather uniform across the companies. Most companies had high expectations to this type of benefit.
Case B-E had specific expectations ranging from high to medium. Apart form Case B these expectations were not realized. In Case C-E the explanation was higher investment than planed. There seems to be connections to the missing benefits on the direct cost parameter. As the goals for the direct cost benefits proved to be difficult to realize the typical reaction were to invest further in production equipment or change suppliers (Case E).
In Case A there were no expectations to benefits from Manufacturing & Logistics. However, during the project it proved that a much simpler assembly system could be installed. This assembly system could be realized at a cost that were estimated to be less than 25% of the traditional assembly system, and, furthermore, the new system proved to be more flexible regarding scaling of capacity.
The discussions on capital bindings regarding Research & Development were quit different throughout the cases. Some companies referred to product configuration systems and emphasized the benefits derived form being able to customize products. Other companies referred more broadly to capturing and systematizing of knowledge.
Apart from Case D all companies had high expectations to this type of benefit.
The most specific goal was defined in Case E. This included development of a product configuration system. As the expected direct cost benefits were not realized the configuration system development were terminated. The project manager left the company.
In Case A-C the goals were formulated less specific in direction of “building knowledge”. In all cases the perceived benefits were considered to meet the initial expectations. Or more precisely, the companies did not precisely know what to expect but what they got were highly relevant and useful.

5.3 Modularization benefits on lead times

Apart form Case A all companies had high expectations to improvement of lead times.
In Case A the expected improvement on lead time in product development were realized. However, due to the new assembly set-up developed in the project they were additional able to shorten lead time in production to less than 30%. This was not expected and had furthermore an impact on other products.
In Case D the lead time in Manufacturing & Logistics was improved. However, the consequences were higher costs.
In Case C and Case E there were high expectations but no realized benefits. In both cases the old saying, “The devil is in the details” seems to apply. The extra time were used to correct mistakes and to compensate for too optimistic time estimates. In both cases it could be pointed out rather specifically were the problems occurred. The reaction was however very different in the two cases. In Case C the problems were regarded as continuous improvement challenges, and in Case E the problems were seen as indications of project failure.

5.4 Summary on implications

In general the realized benefits do not meet the expected benefits in the five presented cases. This picture is the same in the larger sample of 40 cases.
The Modularization Benefit Matrix that have been developed in the project provide a more nuanced picture on the very different types of benefits. In retrospect we have been able to specify the benefits in a way that has facilitated discussion with the case companies. The companies recognize that this more comprehensive view provide a significantly better picture of the benefit portfolio.
It has been clear that there can be a trade off between types of benefits. Typically, the missing benefits from direct cost is balanced with the expected and unexpected benefits on capital binding and the improvements on lead times.

The Cases A-C were from the companies considered as more prototype or test cases. Case D and Case E were full scale projects focusing on critical cash cow products. The intuitive self evaluation done by the companies themselves regarded the cases A-C as successes and the cases D-E as failures. This indicates clearly the missing maturity in the methodologies related to modular products.

It shall be noted that our research methodology specified that the benefits were to be measured 2-3 years after launch. This were in line with the timelines provided by the companies of when to be able to demonstrate benefits. However, our continuing studies demonstrate that many of the expected benefits are realized, but the timelines are often the double (4-6 years).

The discussion with the companies during phase 6 in our research methodology (see section 2) do in retrospect have much in common with the use of the term "option" in financial respect. This reference has earlier been suggested in the modularization literature [Baldwin & Clark, 2000], and recently it has emerged again applied in the Research & Development Management literature [Sneider et.al., 2008]. We regard this to be a potential method to support the discussion of modularization benefits and to develop more precise evaluation methods.

6. Conclusion

The study has demonstarted significant lack of methods and approaches when specifying benefits from modular product development. Partly this can be explained by the weaknesses on methodology and terminology of the modularity phenomenon, but the study has demonstrated that a more specific focus on the different types of benefits can clarify and improve the process.

The Modularization Benefit Matrix has proven to be am efficient tool when comparing expected and realized benefits. It has yet to be tested how well the Modularization Benefit Matrix can support companies when initiating new modularization projects.

Also, the suggested methodology improvement, Platform Template proved to support the companies to understand their modularization efforts. Again, this has been demonstrated in retrospect and has yet to be testet when initiating new modularization projects.

Both the Modularity Benefit Matrix and Platform Template are considered to be able to support companies in their practical modularization work.

From a research perspective the findings must still be regarded as early qualitative contributions. However, we believe that the Modularization Benefit Matrix can be transformed into a survey that can provide more substantial knowledge about expected and realized benefits of modularization projects.

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