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ON THE MARKET ASPECT OF PRODUCT PROGRAM DESIGN: TOWARDS A DEFINITION OF AN ARCHITECTURE OF THE MARKET

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Keywords: market architecture, product architecture, product program design, product family, platform

Abstract

An often overlooked aspect of architecture based product development, is the market aspect. However, without focusing the scope of the product family and ensuring an appropriate layout of product families, variants and features across the product program offerings, experiences show that architecture based product families become rigid, unfocused, prepared for yesterday's market situation, and ultimately lack profitability. This paper will propose to expand the existing notion of coordinating product and production architectures as a means to develop profitable architectures by including an architecture of the market. This is to be interpreted as the 'market perspective' of the product family referring to the design of the product family from the market's point of view. The main result of this paper is the suggestion of a definition of a market architecture with an articulation of its elements, relations, hierarchical nature and raison d'être. Three action research studies show that defining the market architecture serve as a feasible and operational means of addressing the market aspects in architecture development.

1. Introduction

Architecture based product development can basically be considered as a means of solving the conflicting task of providing variety to the market place while seeking to reduce complexity among internal company operations in order to achieve an attractive cost level of a product family. Commonality of activities is here an important ingredient, which is closely related to the commonality of the structural aspects of the product family. However, as there is a very close relationship between the variety provided and the dispositioning of costs during development, it is a fundamental challenge to maximize the variety that generates a high payment willingness without sacrificing internal complexity, and minimize the variety that does not generate any payment willingness. These two standard situations are usually not too difficult to differentiate from each other. On the other hand, the foundation of good decision-making in reality is often much more blurry to reach such unambiguous conclusions.

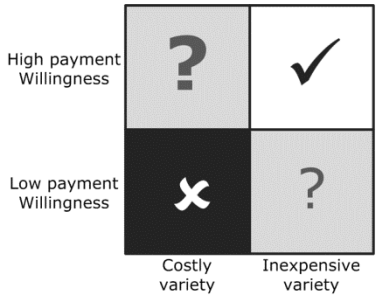

Figure 1: The four standard situations

As seen in Figure 1 the dilemma begins especially when we look upon the situation of high payment willingness with costly variety. The provision of support for decision-making in these 'grey zones' is the theme of the paper, and the contribution offers an operational suggestion for how to improve the foundation of decision-making to handle the trade-offs that arises from this dilemma.
Behind the scenes of these types of decisions are the balancing of the offerings to the market towards the design of the architecture of the product program and the production setup.
In order to account for the hierarchical relations between the meetings encountered by a product family through its life cycle phases, structures can be defined for every life cycle phases, which are to be taken into account during development [Andreasen et al. 1996].

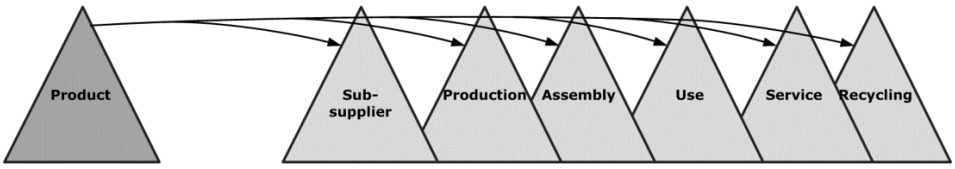

Figure 2: Structure of the product life cycle phases
(redrawn from Andreasen et al., 1996)

From Andreasen et al. [2004] one definition of an architecture is that it is a "*purposefully aligned structure of a system"*. Hence, the deliberate alignment of the structures of the life cycle phases may denominated as architectures. Yet, the architectures vary a lot depending on what life stage is under consideration, ranging from architectures mainly constituted of structural elements (e.g. production) to architectures mainly constituted of behavioral character (e.g. service).

While the production stage usually carries most of the costs, the product and production architectures are previously proposed to be developed in coordination with each other [Mortensen et al. 2011]. However, as an extension to this, product and production architectures do not become profitable if the derived product family is not targeted the market in a coherent and appropriate way. Therefore, we propose the concept of an architecture of the market, as a systematic description of the hierarchical aspects that define the meeting between the product family and the launch on the market [Mortensen et al. 2008]. As with product and production architectures, the key challenge here is to create an optimal *fit* between the market, product and production architectures, which is done through *alignment* [Andreasen et al. 2004]. The three domains of market, product and production follow the classic partitioning from *Integrated Product Development* [Andreasen and Hein 1987].

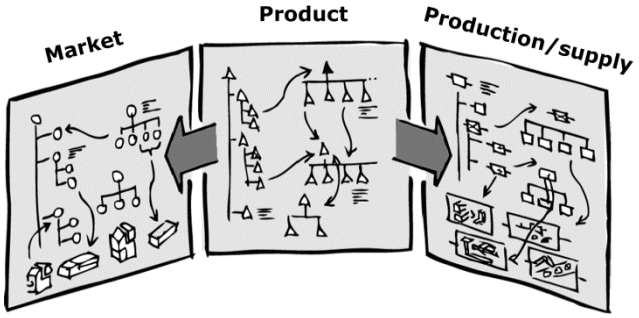

Figure 3: Three architectures: Market, product and production/supply
(redrawn by Kvist, 2009, originally from Harlou, 2006)

The classic paradox of variety and commonality is largely at stake here [Andreasen et al. 2004]. While variety can be considered a relational property between product families, variants and features, commonality is a relational property between different life phase views, referring to the resemblance of the meetings encountered by the products during these phases [Andreasen and Olesen 1990]. Hence, the deliberate balancing of variety and commonality calls for a modeling of the critical aspects deciding the outcome of the trade-offs between these paradoxical goals. This paper suggests to expand the current notion of coordinating the development of product and production architectures as a means to develop profitable architectures by including an architecture of the market.
The paper will briefly describe the motivation for such a market architecture and discuss the requirements for this. Subsequently the literature is screened for the state-of-the-art, followed by a proposition towards the definition of an architecture of the market. Lastly, the experiences from applying the framework are commented upon and conclusions are drawn.

2. Why do we need an architecture of the market?

2.1. The classic pitfalls

From a company perspective, we need an architecture of the market, in order to avoid these classic pitfalls:

2.1.1. Market cannibalization

This is the phenomenon of new product introductions becoming unprofitable, due to significantly overlapping market coverage between product families. This results in lost sales of existing product families that does not justify the new introduction.

2.1.2. The 'sandwich' phenomenon

This phenomenon describes the 'trapped' situation encountered by companies in industries where growth is centered in the high-end and low-end market tiers, and the product families developed lack performance to compete in the high-end markets and lack cost competitiveness to compete in the low-end markets. This leaves them unfocused in the mid-end tier with decreasing sales.

2.1.3. Dead end scaling strategies

A dead end scaling strategy is characterized by the company having no profitable scaling strategy in place, thus using the development efforts on new product introductions without prospects for follow-up releases, upgrades or continuous multi-launches. A dead end is encountered when no natural continuation is planned.

2.1.4. Uneven mix of product properties

If there is no clear differentiation or distinction between which product properties the market expects to be in the product, and which product properties that is capable of positioning the products in the

targeted segment, a common result is an uneven mix of product properties eventually leading to over and underspecified product variants, which drive internal complexity and lack profitability.

2.1.5. Lack of application knowledge

As the variance across product applications can be considered the basic variant driver of a product family, the lack of structuring of knowledge about the requirements from these applications, can distort the focus of which application to target as primary and which application to deprioritize as secondary.

2.1.6. Sub-optimal price and cost points

Even though price and cost in principle always should be separated, the layout of optimal and suboptimal cost-points of the product program should be aligned with price points suggested from a marketing perspective. The pitfall here is to end up with high volume variants positioned in suboptimal price and cost points that do not fulfill the product program target contribution margins, thus jeopardizing profitability of the whole product family.

2.1.7. The jungle of free-text requirements

Many companies have improved their management of requirements, but the classic pitfall here is the lack of classification of requirements that appear in free-text fields with no clear sender or recipient, no differentiation between need/nice to have, and no links to the product architecture. Also, these tend to grow beyond 1-5.000 requirements even for smaller mechanical products, increasing complexity without providing an overview of the dependencies between the requirements.

These pitfalls are recorded through a number of case studies within the research group of the authors, representing a comprehensive challenge for the majority of companies engaged in with product customization, variant management and mass customization.

There is no simple solution to avoid ending up in the situations described above, but the next section will go through some of the basic requirements for defining an architecture of the market with the aim of improving companies' decision-making. The underlying hypothesis here is that by improving the foundation of decision-making, the risk of ending up in these pitfalls will decrease.

3. What should the market architecture enable us to do?

In order avoid the classic pitfalls described in section 2 the definition of the market architecture should enable companies to fulfill these five overall tasks:

3.1. Requirements for a market architecture

3.1.1. Scope the development of product and production architectures

The market architecture should support the scoping the product and production architectures from a marketing point of view. This could include the focusing of which segments and applications to cover and which not to cover.

3.1.2. Elaborating the product applications within these business areas

In order to account for the product applications, the market architectures should support to provide an overview of the similarities and differences among the intended product applications, e.g. by visualizing the requirements of the critical performance parameters.

3.1.3. Make clear and differentiate the product properties

The market architecture should support the allocation of product features across the product variants and ensure an appropriate mix of different product properties across these.

3.1.4. Match the layout of product features with the layout of commercial variants

With multiple intended applications, multiple features to satisfy these, and multiple product variants to carry these features, the market architecture should provide a comprehensive overview of this "layout".

3.1.5. Guide market pricing and match with balanced performance steps (optimal price and cost points)

The market architecture should support to harmonize the feature ranges with performance steps and match with the underlying cost levels in order to maximize the average contribution margins and avoid inappropriately scaled feature levels of product variants.

4. State of the art

Significant contributions have been made to clarify the market aspect of architecture-based product development. These include:

4.1. Adjacent fields of research

4.1.1. Platform strategies

Meyer and Lehnerd [1997] were the first to formulate three fundamental types of strategies in the market segmentation grid combining product segments with price/performance tiers; horizontal leveraging, vertical leveraging, and the beachhead approach. Kristjansson and Hildre [2004] formulated 17 influencing factors on which platform strategy to choose, and divided them into 4 categories: Core competencies, industry situation, market situation, and competitive strategy.

4.1.2. Product planning

Andreasen and Hein [1987] formulated product planning as the continuous parallel activity of determing the product strategy, conduct business search, follow up and supervise on product development activities through coordinating activities. Recent contributions include the challenges of variant management within these efforts [Jonas and Krause 2011]. Also, Riitahuhta et al. [2011] suggests the modeling of a Company Strategic Landscape combining aspects of product, value chain and strategy structuring as means of product-process synchronization

4.1.3. Enterprise Systems Engineering

American literature is oriented towards a wider definition of the concept of architectures [Rebovich and White 2011], working with a practical definition of an architecture as a model that details a system's constitutional and behavioural characteristics in the form of activities, processes, functions, roles, taxonomy and framework. The notion here is that architectures are often rendered through views of deliberate perspectives to overcome human cognitive limitations.

4.1.4. Product properties vs. Customer preferences

Original contributions, as e.g. the Kano model, seek to characterize product attributes from the meeting between product and the customer preferences. This is done by differentiating between basic/threshold/obligatory attributes, performance/positioning attributes and excitement/delighting attributes (some variations of the model includes expected attributes as a sub-kind of performance/positioning attributes that can only be optimized to a certain limit, e.g. noise level). Other coherent frameworks exist for this partitioning of product attributes.

4.1.5. Et cetera

In addition to the fields mentioned above, requirements management, concurrent engineering, and related product management disciplines all mention the subject of the market aspect of architecture-based product development, but it is out of scope of this paper to go into further details here.

4.2. Gap

The current state-of-the-art lacks a coherent description of the elements described in the requirements listed in section 3. Individual elements are touched upon from different theoretical angles and with different aims, but these are not consolidated from a product architecture-based viewpoint. Aside from the lack of coherence, most contributions within this field consider the market perspective of architecture development as 'focusing on maximum variety' by default, without going into details about optimal *fit* of product applications and product features. Hence, some contributions become isolated in the product domain by e.g. developing advanced numerical optimization algorithms that seek to optimize the configuration of product families based on very simplistic product models. These methods might satisfy analytical needs, but they do not fulfill the requirements described in section 3.
Based on this sub conclusion, section 5 will elaborate on the suggested proposal of an architecture of the market.

5. The market architecture

5.1. Towards a definition

To overcome the challenges listed in section 2 and fulfill the requirements from section 3, a description of an architecture of the market is suggested. The architecture of the market should serve the development product programs by describing them from the market's point of view, while maintaining a hierarchical structure that can act as a malleable object of alignment towards the product and production architectures. Figure 4 shows the three architectures with their five levels. Section 5.4 will elaborate on the definition of the included elements.

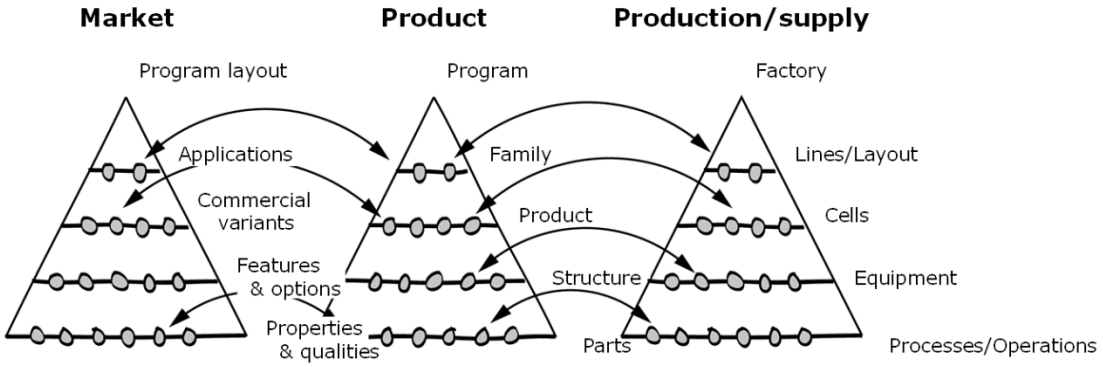

Figure 4: Alignment of market, product and production architectures
(expanded from Mortensen et al., 2008)

5.2 Use

The argument here is that modeling these three aspects concurrently during development is a prerequisite of creating attractive product programs. Alignment is seen as the mutual phenomenon of creating an optimal fit between the different architectures through activities of synthesis. However, in some cases of e.g. redesign or DFM activities, certain architectures can remain stable.
The architecture of the market is suggested to be applied both for mapping the market aspect of a product program for analytical purposes, and for maintaining an overview of decision-making during updates or new product program development.

5.3. Visualization

A visualization approach is chosen as means of staging the definition of architectures as boundary objects between the involved domains. Architectures, being a rather abstract phenomenon, can be very difficult to manage without appropriate models. In the attempt of bridging coordination between multiple domains with multiple levels of understanding, visual modeling is considered a prerequisite of intervention and malleability.

5.4. The five levels

In Figure 4, the three architectures are shown with their five levels. Figure 5 shows an elaboration of the five levels of the market architecture. As this is a general presentation, naturally the levels vary from case to case. However, a key aspect presented here is that the market architecture needs concurrent definition of all five levels.

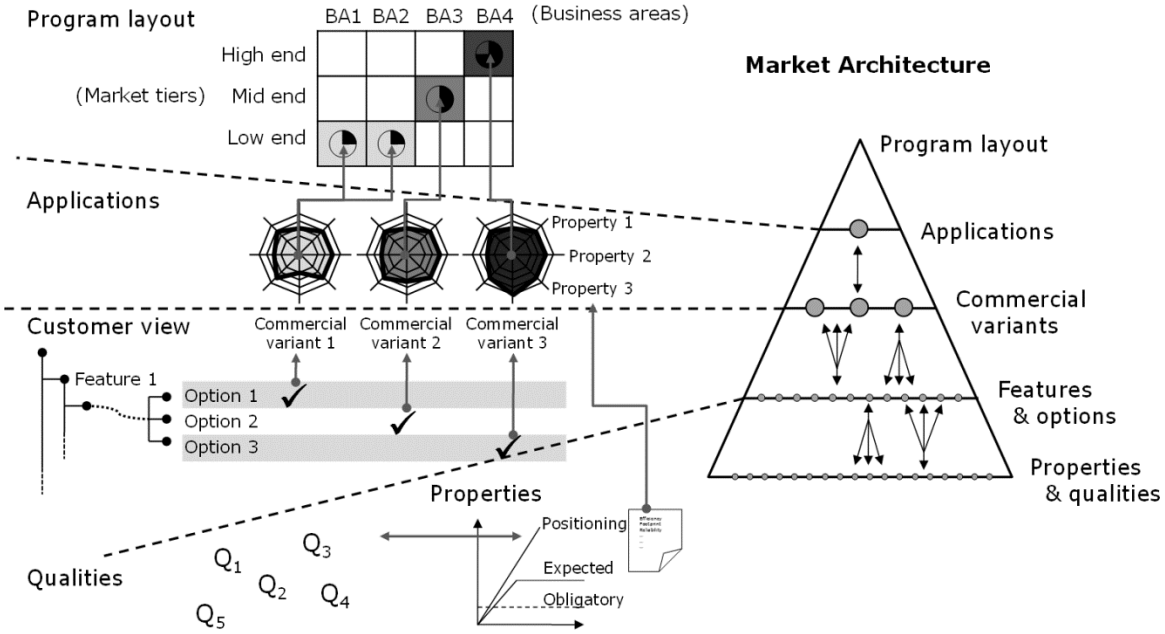

Figure 5: The 5 levels of the market architecture

The arrows between the levels to the right are indicating that there can be a one-to-many relationship between the three lower levels in both directions.

5.4.1. Program layout

Based on the market grid introduced earlier, the overall task of the program layout is to describe which business areas/segments to serve and which to leave out. The program layout expands this concept by adding the market life cycle stage to indicate whether a product family is newly introduced, maturing, or declining. The horizontal structure can indicate business areas or segments usually having a simple fit to the product applications. The mapping can help focusing the product architecture towards the most appropriate and favorable segments. Included in the program layout is also an indication of future derivate product families in order to avoid the pitfall of dead end program scaling.

5.4.2. Applications

The applications of the product are basically a segmentation of the market based on common use situations. The visualization of the requirements from each application (e.g. by radar diagrams) can serve to prioritize which applications to target the product program towards, while serving as a valuable input for differentiating what is variable between applications and what is common. The application overview is used as a mediating function between marketing and engineering for balancing wishes and possibilities, but also as a benchmarking tool for assessing the innovation height of a new product program compared to the recent product program. Applications *can* be similar within business areas/segments and across market tiers; in this case, it is the level of fulfillment that differentiates the product families from low-end to high-end.

5.4.3. Commercial variants

The commercial variants are the actual product variants of which the marketing department usually carries the market responsibility. In engineer-to-order companies, these do only exist retrospectively as

commercial variants are customized for individual customers' specific needs. The projected cost of the commercial variants are mapped towards marketing's best guess of market price ranges. This allows for a comparison of the contribution ratios across the product program to evaluate the grouping and allocation of features and options across the commercial variants and improve product program contribution margins.

5.4.4. Features and options

The overview of the commercial variants are combined with the customer view [Harlou 2006]. Here the mapping of features and options are done towards these variants, and it is relevant to focus which features and options to include during the first product launch and which to postpone for future launches. Some features might be de-scoped and omitted if the means of realization is not in place, payment willingness is considered absent, or if the overall market offerings are regarded as being too wide and in need of focus. The main task of linking the features and options towards the varying applications is to separate the cost-effective and reusable 'core' from the variations provided by these.

5.4.5. Properties and qualities

The lowest level contains the individual product attributes of interest to the customer, namely product properties and product qualities. A well-working partitioning here is the differentiation between obligatory (must), expected (improvement to a certain level) and positioning properties (differentiating from competing products), or simply just need/nice-to-have. In some industries the existence of excitement properties (*delighters* that surprise the customers if included) are just as important. This definition might seem loose, but due to variation between industries and products, no general partitioning is suggested here. This information is often stored in requirements lists, but it is important to link these directly to the features and options fulfilling these requirements.

5.5. Linking the architectures

As time-to-market is mostly decided by the size of the engineering efforts, and investments are mostly decided by changes implemented in production, it is of fundamental importance to link the mapping of the market architecture to the product and production architectures, and optimally develop these three concurrently. The market architecture constitutes the basis of a focused product architecture, thus making all efforts of focusing the production/supply tasks dependent on the ability to focus the market architecture.

6. Experiences from application

The concept of the market architecture has been tested, refined and developed through a number of action-based research studies. Three of them are shortly commented here:

6.1 Early-stage architecture development

In the context of a larger industrial manufacturer of mechanical products, a new promising technology was considered the corner-stone of a new generation of product families. To ensure forward compatibility of the technology and prepare for laying out a path of potential future launches, architecture work was engaged. Since the project was in its early stages, the work was focused on the interplay between the market and product architecture. Here, the market architecture provided an overview of the product applications, the commercial variants and the possible features and options. The main task here was to separate the application dependent options from the reusable core to prepare it for mass production and attractive cost levels. The results was a proposal for the first generation of a product family architecture with prospects of a line of possible future derivatives, matched with an overview of the variations between proposed variants and selectable options. Also, the market architecture helped to select prototype installations that represented the total spectrum of possible future variants, and to focus the basic scaling principles of the product architecture in alignment with the market architecture.

6.2 Performance critical OEM-supplier

In a world leading OEM supplier of performance critical components for the energy industry, research work was initiated in order to clarify how the company could benefit from architecture thinking and to test and improve the modeling techniques. The company had severe difficulties with their time-to-market, and no reuse existed between engineer-to-order customer projects. Also, the investment level and resource consumption of a standard development project was too high to serve other than a few large OEM customers. The definition of a market architecture helped to scope the definition of coherent product and production architectures. By creating an overview of the dynamics in the program layout and by systematically listing the requirements from lead applications, the market architecture helped to focus engineering efforts. This created a basis for reuse of engineering resources and production equipment, shorten time-to-market for derivative products, and remove the risk elements from high initial investments in production equipment having the tendency to scare away OEM customers unwilling to co-finance such start-up activities.

6.3 Fundamental architecture selection

In an industry leading electronics company, a major program development project was severely postponed. As the company is a result of mergers in the past, different product architecture strategies were present alongside each other, and the major dilemma was whether to switch to a fast-track development program using current technology with market launch in 2012/2013, or accept the postponement and develop the product program as initially proposed being ready for launch in 2015. With contradictory interests and different perceptions of the market situation, the modeling of the market and product architecture of the development program was initiated to evaluate which fundamental architecture selection options would serve the company the best. The classic pitfalls of multiple development projects competing for the same sales (market cannibalization), and dead end scaling strategies were largely at stake here. The basic trade-off between maintaining the market position with the fast-track alternative, or wait and improve the feature offerings with possible loss of market share, was elaborated in the dimensions described in section 5. This modeling of the alternative market and product architectures served to improve the decision foundation of the company, e.g. by aligning the scaling strategy of the product architecture with the scaling strategy of the market architecture.

7. Discussion

Only dispersed bodies of literature have treated the market aspects of architecture-based development of product programs and families systematically. This contribution should be regarded as another important piece of a puzzle outlining a suggested framework based on the authors' practical experiences within this challenging area. Thus, the contribution presented here does not represent a complete framework on its own, but serve as a contribution to the framework of the authors (represented in Figure 4) and the scientific body of knowledge.

An important strength in this contribution is that the application of the concepts presented can be applied without the need of crossing huge barriers. Many companies might have some elements of the market architecture well documented and under control when looking retrospectively at current product programs, but the contributions presented here underline the importance of modeling the market architecture proactively during development and in coherence with the product and production architecture. A possible deficiency with the concepts presented here arises from the same situation, as the need of adaptation (and competence to do this) is needed in order to integrate the work with the market architecture successfully.

8. Conclusion

This paper has presented and elaborated on the definition of an architecture of the market. Is has been described how the definition can support the difficult decision-making of providing sufficient variety in product programs to maximize payment willingness from customers without sacrificing internal complexity. The market architecture definition has been motivated through the outlining of seven

classic pitfalls encountered by companies failing to scope and fit product programs appropriately from the market's point of view. The response to these challenges was formulated through five requirements for the definition of an architecture of the market, and the state-of-the art was screened and briefly summarized to identify the knowledge gap. Subsequently a proposal towards a definition of a market architecture was described shortly including five levels, and the successful application through three case studies was shortly reported.
Implementation of architecture thinking across market, product and production domains, however, is a very challenging task. Many preconditions and prerequisites exist for successful implementation, e.g. a modern IT infrastructure, organizational ownership, sufficient resources/competences and high-level anchoring of the initiatives.
Regarding further work, the detailing of the modeling elements included in this presentation can be mentioned. As this has been a short and general presentation, the further detailing, testing and refinement of the modeling techniques behind the market architecture are relevant activities to succeed this paper. The generalizability can be considered a strength of this presentation as well as a weakness, since reality in many cases needs a higher resolution of detailing that this presentation format allows for.

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