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PLATFORM EVALUATION USING EXCPLICIT MODELLING: A CASE STUDY

L. Munk and N. H. Mortensen

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1. Introduction

Multi-product development can be utilised with platforms in order to achieve increased customisation, reduced development time and costs, reduced manufacturing costs, reduced manufacturing investments, reduced systemic complexity, lower risk and improved service. Establishing a platform is though still a challenge. A part of this process is to evaluate and optimise alternative solution concepts in relation to the before mentioned benefits. In literature there are numerous examples of matrices, algorithms and indices that can be applied when evaluating platform or modular alternatives. These are often based on weighted scores for the platform's properties regarding different criteria and create a ranking of the solutions. The actual consequences of selecting one solution are not described with these kinds of evaluation. It is our experience from working in Danish industry that in many projects this lack of overview of the actual consequences undermines the confidence in the solution and inhibits decision-making. To achieve knowledge of the actual consequences it is often necessary to explicitly model the most critical parameters and their relations in the market, product and production domain. This explicit modelling is challenging and time consuming, especially in platform development when several alternatives are considered for not only one but multiple products, but if the most critical parameters can be identified and their relations can be described, IT tools make it possible to create tools that can calculate the consequences immediately and hence support the evaluation and optimisation of the platform solutions.

This paper describes a case, where a platform was established in the LEGO Group. The solution evaluation process was mainly based on the explicit modelling of critical parameters and their relations. During the process two IT tools to support the evaluation process were developed and used. It is the aim of this paper to identify benefits of this approach.

2. Background

Many methods of evaluating platform solutions are based on indices and use assessment and weighing with numerical figures or metrics [Ulrich & Eppinger, 2000], [Erixon 1998], inspired by existing methods for concept selection single product development as described by Pugh [1991] or Pahl & Beitz' general evaluation methods for individual product development [Pahl & Beitz, 1996]. Pahl & Beitz themselves suggest, that modular solutions are evaluated based on technical and economical criteria, but do not describe these in details. Other methods introduce indices of modularity based on algorithms [Guo & Gershenson, 2004] to measure the best performance of modular design, but these do not give information of the consequences of the actual solution.

It is our experiences from Danish industry that these assessed metrics are difficult to interpret and that they are not considered as sufficient to base an important decision as a final platform solution decision on. Some critical issues need to be considered on a very detailed level to know the consequences, before companies are interested in to commit to a platform. Hence there is a need for an evaluation that explicitly models the critical parameters of the platform solution, the derived products and the architecture of different lifecycle systems (product development, production, assembly etc.) that it influences.

Based on Theory of Dispositions it is possible to explicitly model effects in terms of time, cost, quality etc. (The seven universal virtues) of a solution based on its specific parameters and their relations to critical parameters of the lifecycle systems [Olesen, 1992]. This does also apply for platform solutions: By understanding the relations, it will be possible to create synergies within the activities of the different lifecycle systems and improve the overall performance of the entire product assortment. This process is defined as aligning the architectures of the products and the different lifecycle systems [Andreasen et al., 2004]). We define a platform as a system that defines the rules for and enables exploitation of the alignment of architectures with the purpose of achieving some of the benefits of modularisation across a range of products.

With the computer tools of today it is possible to model selected parameters and their relations to describe the consequences of a platform solution. The challenge is to understand what such tools should describe and how to they can be designed, which is not described in the literature.

Often the modular architecture of a platform are based on variance and commonality of the product variants [Robertson & Ulrich, 1998], but the challenge of establishing a platform can be described as meeting the requirements of product variety (the market system) and requirements of an optimal production (the production system) in the product assortment design (the product system) and hence many companies would benefit from using a market and manufacturing perspective [Kusiak, 2002] in their considerations. The models of Integrated Development [Hein & Andreasen, 2000] describes a framework of market, product and production systems, where the product is established during the product development process and has to satisfy the demands from both the market and the production system. The platform development process can be compared to this, and this approach has been used in the Product Family Master Plan [Mortensen, 1999], but being a document it does only describe a final solution, and not effects of this and alternative solutions.

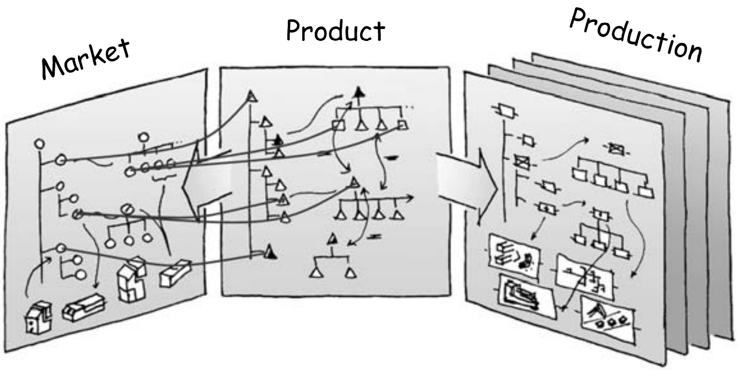

Figure 1. Illustration of the structures of market, product assortment and production systems and the relations of different parameters in between the systems [Harlou, 2005]

In the following case study the evaluation process was supported by two modelling tools, developed and used in the process, enabling the immediate and explicit calculation of effects of alternative solutions. The two tools describe the relations between critical parameters of the market and product systems and the product and production systems, respectively, therefore the market, product, production approach will be used as a descriptive framework. To learn more about the use, benefits and drawbacks of this approach this case study was performed.

3. Method

The case study was performed in LEGO Group spring 2005 with the aim of studying how modelling tools based on market-product-production relations supported the development of a platform. The development and use of the tools was in this particular project in the evaluation phase. The tools were developed based on requirements, critical parameters and their relations from both the market and production system. The researchers participated in the development of the tools and were observing during the use of the tools. The researchers participated in the weekly project meetings and workshops. Hence the study was performed as action research (i.e. the researchers themselves took part in the project).

After the project participants were interviewed in a group about their positive and negative experiences regarding the development and use of the tools. The issues of this interview were:

- Expectations before development and use of the tools
- Reduction of evaluation time
- Number of solutions considered
- Quality of decisions
- Challenges in development and use of dynamical modelling tools

4. The platform project – the Pre-pack Platform

4.1 LEGO Group and platform development

LEGO Group is a global company that develops and manufactures toys. In 2004 they were the 4th largest toy manufacturer (in terms of sales) worldwide. Their toys mainly consist of a variety of coloured plastic blocks which all can be connected and combined into various models, depending on the specific theme of the product. Globalisation has lead to fierce competition on the toy market and combined with a decline in the market demand, this left LEGO Group in a financial crisis that made them reconsider their entire business. Platform thinking has been one of the approaches to improve the business, and as a part of this initiative the Pre-pack platform project was initiated.

4.2 Aim and starting point of the platform

The aim of the Pre-pack platform was to exploit the high number of common bricks across a range of products in the packing process to achieve faster product development, reduced production cost and level out production peaks with minimum risk. In the early phases of the project alternative conceptual packing solutions and equipment were considered, but due to the necessary investments and LEGO's financial situation the starting point was to exploit existing equipment. The existing range consisted of 16 products, where 6 products were introduced and 6 products were phased out every year. Each product consists of a number of pre-packed bags with bricks.

The platform project should investigate if it was possible to configure a large part of the products from a combination of the most common bricks in so called pre-packed *module bags* bags as illustrated in figure 2 and if was possible to achieve the desired benefits.

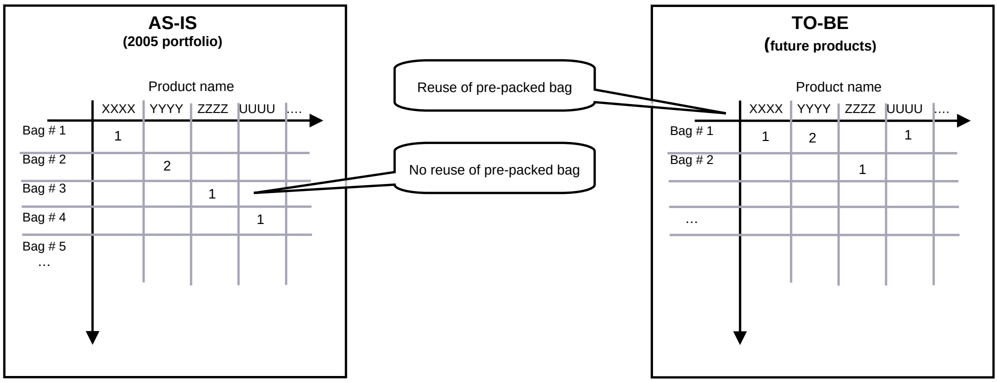

Figure 2. The platform and the module bags could make it possible to configure the various products from a few bags

The challenge of this was to make the optimal combination of bricks in the module bags – the grouping of the bricks in bags that would give highest degree of reuse across the products to exploit it in the production (the production view) - in this case specifically the packing process - and still meet the requirement of variance for the individual product (the market view). But which of the specific module bag solutions that would satisfy this in the best way was difficult to foresee. Hence it was for the evaluation of the numerous alternative bag contents with numerous different combinations there was identified a need for an explicit modelling of the consequences of alternative solutions of this study, the modelling tools were developed and used.

5. The modelling tools

The challenge was to evaluate which bags satisfied the overall aim of the platform and the demands and critical parameters from market and production views. Many alternative solutions seemed to be feasible, but the only way to identify the optimal solution was to investigate how well the market demands were meet for each individual product and how well the module bags fitted into the packing system. To meet the need of explicit modelling of the consequences, two tools with different purposes were designed to evaluate the alternative solutions:

- **Market-Product (MP) configurator** - illustrating the alignment of the market and product view showing how well a certain combination of modular bags was capable to fit at given product
  Input: The combination of alternative bags and the approximate content of bricks of the desired product
  Output: An overview of the bricks that shows differences between the content of the bags and the desired product, the relation between designs, the relation between colours and the price

- **Product-Production (PP) configurator** – illustrating the alignment of the production and product view showing how well a certain module bag fitted into the production facility
  Input: The module bags content of bricks and which type of production equipment
  Output: An overview of how many packing lines are needed to pack a bag and how well their capacity is exploited

The tools facilitated an immediate calculation and visualisation of consequences of alternative solutions regarding the market and production view, but do not present a final evaluation of the result. They present the critical values and let it be up to the project group to evaluate the quality of the result make the final decision. Combined with a systematic approach to evaluating the solutions it creates an opportunity to evaluate more concepts and in way that makes it easy to compare them, and make a decision of which alternative is the best.
The actual programming of the tools required basic programming skills based on data from the company's ERP systems and a few loops in the development, when team experienced the effect of the tools and suggested improvements and extra features. The development of the programs took about 20 hrs and was conducted in cooperation with a team member and the researcher.

5.1 Identification of the parameters from market and production views

The input and output parameters of the tools were identified prior to the evaluation phase as the demands and critical parameters of the market and production view:
For the market view they were based on input from marketing and the designers, whereas input to the production view was given from packing developers and production planners. It was identified that the designers had criteria like relationship between colours, size distribution and price to make what the designers called "a good bag". Hence the requirements from the market view were that the bags should configure the products with the relation between sizes and colours at the specified price.
From the inputs to the production view the existing rules for bag packing optimisation were described. These rules were based on the capabilities of the packing equipment and varied with the number of different elements in a bag and their size distribution and the most important critical parameters production time were related to batch size and changeover times and the maximum size of the bags.

5.2 Parameters of and relations to the product view

To make the explicit modelling of consequences, the relevant parameters of the module bag solutions in the product view had to be identified. Knowing the critical parameters of the market and production view, the relevant parameters of the product view and their relations were identified by analysing by discussing alternative solutions and consider the change and dependencies in between the parameters. Knowing the relations made it possible to set up the tools that calculated the consequences based on varying values of the parameters. The quality of the tools depends on how precisely the relations are formulated, which makes it a challenging and critical issue. From the experience of this study it has not been possible to derive general guidelines, except that practice and loops raise the quality. Table 1 "Critical parameters of the Pre-pack Platform" describes the identified most important parameters and three examples of relations between them for the pre-pack platform solution. The identification of them is not described and they are not defined in details, due to the format of this paper, but may serve as an example of critical parameters and how they are related. All the relations create a complex pattern, which is handled in the tools. The three examples of relations that are shown in table 1 are between no. of bricks in product and no. of bags in product, brick design and equipment changeover, and no. of bricks in bag and no. of production lines respectively. The relations are briefly explained: A bag can only contain a limited number of bricks and hence the number of bricks in a product is related to the number of bags in it; each brick design has its own production equipment and hence it requires equipment changeover; the production lines have a specific number of counting stations, that will be filled up depending on the number of bricks in a bag.

Table 1. Critical parameters of the Pre-pack Platform

Market view	Product view	Production view
• Price • No. of bricks in product • Brick design • Relation between designs • Colours • Relation between colours	• No of bags in product • No. of bricks in bag - described by design and colour • Bagfoil	• No. of bag types • No. of production lines • Equipment changeover • Size of batches • Production time pr. bag • No. of type of bricks

6. Using the tools in the evaluation process

Prior to the evaluation process 16 alternative solutions of the modular bags were designed. There were no internal constraints in between the bags, so they could be combined in every way.

The tools were used during the project work by having the team gathered and projecting the result matrices on a screen so everybody could se the result of the alternative combinations and give input to the evaluation and optimisation. The process of evaluating and optimisation was very iterative, and both tools were used in both to immediately see the consequence of the changes that had been made to the concepts and evaluate them. All the module bags had been evaluated with the PP configurator for a rough optimisation towards the production rules. Using the MP configurator each individual product was configured in two or three alternative ways with preference with the criteria of a minimum number of bags. All used bags across the existing, planned and future products were considered to see how many variants of bags were necessary. If a bag was optimised in respect to a certain product, it would be checked how the change affected other products it was a part of, facilitated by the MP configurator, and the packaging set-up, facilitated by the PP configurator. If a bag was used in only one product it was checked if it could be replaced to keep the number of module bag variants as low as possible. In this way 48 product concepts were considered, in average three per product.

7. The final Pre-pack Platform

This new platform made it possible to base in average 60 % of the content of 16 products on the common bags and halved the types of bags. The goal is to keep the same percentage for future products and this goal has achieved commitment from the stakeholders. The goal has made it possible

- to reduce the product development time with 25 % due to elimination of activities connected to bag variants
- to move 80 % of the production to low season due to the lowered number of alternative bags and the reduced risk of obsolete stock.
- to reduce production costs and production hours significantly due to low season production and bigger production orders.

No investments were needed to implement the platform, and the only expense for the platform was the development costs.

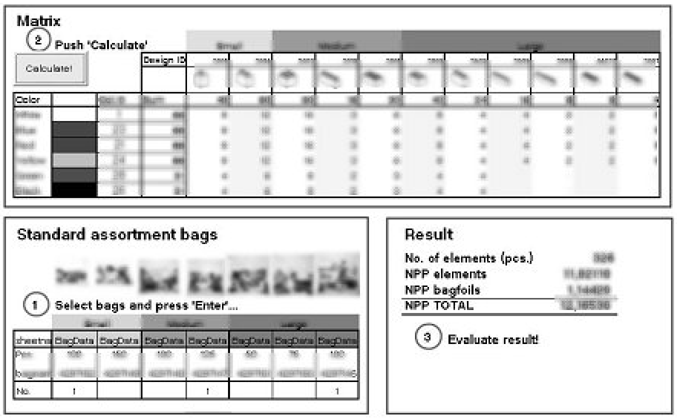

Figure 3. Screenshot of the MP configurator that immediately shows the current price and coverage of the selected parameters "design" and "colours" with a combination of module standard bags and their price (Blurred on request from LEGO Group)

Beside from the module bags the final platform also consisted of a product development and production system that made it possible easily to derive new products from the platform. These systems support the product development, because the introduction of the platform means that the product development task must be performed differently: Now the entire range of products are considered simultaneously and are committed to follow the platform rules and meet the goals of it. In this process the MP configurator is used in the configuration of products as a useful tool. The production the planning task is also performed differently with new key performance measures and it is based on the need from the entire product range instead of on a single product. This change of behaviour is essential for the success of the platform and may be a bigger task than creating the technical part of it.

8. Results

The outcome of seeking to apply relation-based modelling tools with a market, product, and production approach as support in the establishment of a platform was the development and use of two tools in the process. The outcome of the overall process was a platform, which was implemented in LEGO and is functioning today.

From the interview with the participating team members regarding the approach and the tools in the platform development project, following statements were gathered. The questioning of the project participants was focusing on the issues mentioned in the method sections:

- Expectations before development and use of the tools
  The participants were positive about the usefulness of the tools from the beginning, but some said that they did not see the potential of the tools before they were developed and could test the tool prototype.
- Reduction of evaluation time

The participants estimated that to go through the same evaluation and optimisation would have demanded four times the amount of time without the tools as it did with the tools, which meant a reduction of the use of manpower in these processes to less than 40 %.

- Number of solutions considered
  The participants believed that because of the easiness of investigating the consequences of an alternative concept a higher number of solutions and a wider space of solutions were considered.
- Quality of decision
  The participants believed that the process with the tools had made them more confident in the final solution, than with a process without. They pointed out the fact that all the alternatives could be compared within a very short period of time and in an equal frame, which made the evaluation more objective and comparable as the reason for this. Based on this they concluded that they thought the quality of the decision had been improved by using the tools.
- Challenges
  The participants realised that the skills required to develop the tools was not initially present in the project group and hence they had to be developed during the project, which is an obstacle for the involvement of such tools.
  They also experienced that it was a challenge to identify relations from market and productions and decide on clear measures, since it otherwise impossible to make such tools and that it is necessary to have a fulfilling representation on the products and modules to make it meaningful to interpret the output.

9. Discussion

The benefits achieved in this case study by using explicit modelling may be generalised, but it can be argued that since the products of this case study are to some extend already modularised and has very simple interfaces, which makes it possible to describe the relations of the critical parameters precisely as rules and calculate consequences from different solution precisely. This may have eased the process, but the authors believe that it is possible to use same approach successfully for other modular problems. Using e.g. a car manufacturer example deciding on which motors he should make to cover the demands of the different cars and exploit his production system. He has to evaluate the alternative solutions based on the critical parameters from the market and production view, and it must be possible to identify relations for these and model them explicitly and achieve an improved decision base. The challenge is to identify and formulate the relations into rules to make it possible to set up a model that can model the consequences explicitly.

10. Conclusion

This case study has investigated the development and use of explicit relation-based modelling tools with a market, product and production approach in a platform development project. The results from this case study indicate that there are benefits to achieve by applying tools with such an approach, in the areas of shortened platform development time, increased number of concepts considered and quality of decisions. They also indicate that there are challenges in developing such tools, such as lack of the required skills and identification of relations, and that the project participants are not always capable of assessing the potential of using such a tool. Regarding this issue the application may have limits and more research most be conducted to generalize these limits. Since these indications are only based on this case study, further research must be conducted to verify the above as well as in a describing a general approach to identify and specify relations that makes it possible to model the consequences explicitly.

References

Andreasen, M. M., Mortensen, N. H., Harlou, U., "Multi Product Development: New models and concepts", Proceedings of the 15. Symposium "Design for X", Neukirchen, 2004.

Erixon, G., "Modular Function Deployment – A Method for Product Modularization", The Royal Institute of Technology, 1998.
Guo, F., Gershenson, J. K., "A Comparison of Product Design Methods based on Improvement and Iteration", Proceedings of DETC'04 ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September 28-October 2, 2004, Salt Lake City, Utah, USA.
Harlou, U., "Developing product families based on architectures", Ph.D. Thesis, Technical University of Denmark, 2005.
Hein, L., M. Andreasen, "Integrated Product Development", IPU, Lyngby, Denmark, 2000.
Kusiak, A.,"Integrated product and process design: A modularity perspective", Journal of Engineering Design, Vol.13, No.3, 2002, pp 223-231.
Mortensen, N., "Design Modelling in a Designer's workbench – Contribution to a Design Language", Ph.D. Thesis, Technical University of Denmark, 1999.
Olesen, J.,"Concurrent Development in Manufacturing – based on Dispositional Mechanisms", Ph.D. Thesis, Technical University of Denmark, 1992
Pahl, G., Beitz,W., "Engineering Design – A Systematic Approach, Springer-Verlag, Berlin, 1996
Pugh, S., "Total Design: Intergrated Methods for Succesful Product Engineering", Addison-Wesley, Wokingham, UK, 1991
Robertson, D. and Ulrich, K., "Planning for Product Platforms", Sloan Management Review, Summer 1998, 1998, S. 19-31.
Ulrich, K. and Eppinger, S., "Product Design and Development", McGraw-Hill Higher Education, 2000.

Lone Munk
PhD Student
Technical University of Denmark, Department of Mechanical Engineering
Nils Koppels Allé, DTU – Building 404, DK-2800 Kgs. Lyngby, Denmark
Tel.: +45 45 25 62 04
Email: lmu@mek.dtu.dk
URL: http://www.mek.dtu.dk