UNIVERSITY *of* VAASA

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Becoming Lean

A Case of Finnish Boating Industry

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Julkaisun nimike
Kohti lean-tuotantoa – Case-tutkimus suomalaisesta veneteollisuudesta

Tiivistelmä
Tutkimuksessa esitellään konseptiveneiden kehitysprosessi ja lean-tehtaan suunnittelu. Työssä on esitelty lean-tuotannon periaatteet ja rotaatiovalumenetelmä. Tuotekehitystä edelsi segmentointi, jonka tulokset tulivat prosessin ohjaaviksi tekijöiksi. Segmentointiprosessi paljasti, että kohtuullinen hinta, turvallisuus ja helppo huollettavuus ovat niitä ominaisuuksia, joita tutkimuksen kohderyhmä arvostaa eniten.

Kohderyhmä ei käytä venettä osoittaakseen sosiaalista asemaansa. Vene on heille laite, jota käytetään veneilyyn tutuilla alueilla sekä väline kalastuksen harrastamiseen.

Kokoonpanon suunnittelu ja rotaatiovalun vaatimukset vaikuttivat lopullisen tuotekonseptin luomiseen. Ehdotettu tuotantolaitoksen layout, samoin kuin tuotanto- ja kokoonpanoprosessit, luotiin lean-filosofian pohjalta. Se tarkoittaa arvon luomista asiakkaalle, kustannusten alentamista ja hukan poistamista sieltä, mistä se on mahdollista.

Kustannuksiin kiinnitettiin erityistä huomiota. Tutkimus osoittaa rotaatiovalun implementoinnin taloudelliset edut. Tutkimus osoittaa myös, että rotaatiovalun tuotantotekniikka on linjassa lean-tuotantofilosofian kanssa.

Asiasanat
Veneteollisuus, tuotekehitys, rotaatiovalu, lean-tehdas

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Abstract

This document is aimed at presenting the process of a boat concept development and a lean factory planning. The principles of lean production are discussed as well as a promising manufacturing method of rotational molding. Product development was preceded by segmentation which results became guiding principles for the process. The segmentation process revealed that reasonable price, safety, and ease of maintenance are the features that target customers value most. Moreover, target groups do not treat boat as a manifestation of social status- a boat will generally be a device for short-distance sailing within familiar areas as well as for enjoying fishing alone.

Design for assembly and requirements or rotational molding also influenced the creation of the final product concept. The proposed factory layout as well as manufacturing and assembly process was guided by lean philosophy- creating customer value, decreasing costs and eliminating waste whenever and wherever possible.

The cost issue was given special attention- financial justification of rotational molding implementation is summarized and presented in the document. This shows that the manufacturing technique of rotational molding goes in line with lean manufacturing philosophy.

Keywords

Boating Industry, Product Development, Rotational Molding, Lean Factory

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We would like to thank Jussi Timonen from Plastweld Oy for sharing his expertise and professional knowledge about rotational molding. We would also like to thank Janne Vähätiitto from Oy Finn-Marin Ltd for his valuable comments on boating industry and challenges that manufacturers face in their day-to-day operations.

Without professional support from Technology Center Oy Merinova Ab we would not be able to precisely justify the introduction of rotational molding in terms of costs. Therefore, we would like to thank Seppo Murto and Mika Konu as their expertise proved to be invaluable in the process of muddling through the digits.

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Vaasa, 15th of May, 2011

Anna Rymaszewska

Mikael Ehrs

Janne Pekkala

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Abbreviations

DFA Design for assembly

DFM Design for manufacturing

SMED Single minute exchange of die

SMEs Small and medium enterprises

1 INTRODUCTION

The current situation of the Finnish boating industry imposes changes on manufacturers. Growing manufacturing costs as well as competition form low labor cost countries. Boating industry in Finland is characterized by small companies dispersed around the country and using traditional manufacturing methods such as spray lamination. The dominance of SMEs has both advantages and disadvantages. On one hand, small and medium enterprises might not have the resources and knowledge base to effectively develop and change their manufacturing methods. On the other hand, according to Yaman (2008) such companies are capable of gaining competitive advantage providing they improve their speed, efficiency and quality of operations which might be challenging with limited resources available. SMEs are known to be more flexible and capable to quickly react to demand changes Moreover, the author claims that SMEs are and will be important part of both national and international economies.

The overall current situation of the boating industry in Finland is rather positive. According to Finnish Marine Industries Federation (Finnboat Website, 2011) by the close of 2010 the turnover increased by 26,8 %. Table 1 illustrates the increase:

Table 1. Wholesale delivery statistics for small craft and motorboats-year 2010. Source: www.finnboat.fi

Item	**Units**	**%**
Boats below 6 meters	7936	+ 7,1
6-8 m boats	652	+ 24,0
8-10 m boats	94	+ 28,7
Boats over 10 m	36	+56,5

It is worth noticing that in the segment of boats below 6 meters is the most popular and there also have been a considerable increase. This particular segment is the core interest of this document.

The industry prospects as researched by Finnboat are generally optimistic. In the survey conducted by Finnboat at the beginning of January, Finnboat member companies were asked about their expectations with respect to turnover and labor requirements. The results are presented in Table 2.

Table 2. Industry prospects for 2011. Source: www.finnboat.fi

turnover	**2011 %**	**2010 %**
less than for 2010	3	12,5
the same as 2010	31	30,8
greater than 2010	66	56,7
personnel	**2011 %**	**2010 %**
less than for 2010	6	7,8
the same as 2010	64	73,4
greater than 2010	30	18,8

Even though the overall situation of the boating industry is rather positive and manufacturers are not expecting any drastic drops in turnover, there is a risk constant risk of inexpensive boats inflow from low labor cost countries. Moreover, environmental regulations are about to change soon and the spray lamination method will have to be abandoned as it produces harmful fumes. This justifies the need for more innovative approach to boat design and manufacturing. Target customers might be conservative in their preferences but they value high quality, reliable, long lasting products just as much as they value reasonable price. Therefore, the aim of the project which this paper refers to, guides the product development process as well as the choice of the manufacturing method.

2 THEORETICAL FOUNDATIONS

2.1 Overview of the lean thinking

The origins of lean thinking can be found in the activities of Japanese manufacturers, in particular Toyota Motor Corporation. However, the development of lean concept was a result of dynamic learning process that comprised of adapting and adjusting best practices from outside the automotive industry as well (Hollweg, 2007). Back in the 1960´s Japanese companies were forced to develop an alternative to American mass production. Due to the scarcity of resources and intense domestic competition in the Japanese market for automobiles alternative development paths needed to be discovered. Japanese companies simply could not follow the mass production pattern. The country is small, crowded and resource-poor as Schonberger (1982) states. This implies that the Japanese were forced by the external environment to invent creative solutions. When the resources are scarce waste cannot occur and effective utilization of what is available becomes essential. According to Womack et al. (1991) lean production is lean because compared to mass production it uses less of everything- less human effort in the factory, less manufacturing space, less investment in tools and less time for the new product development process. Becoming lean also implies inventory reduction, less defective products and scrap as well as greater product variety. Womack et al. (1991) state that the main difference between mass and lean production exists is in their ultimate objectives.

Mass production tolerates a certain number of defects, sets an acceptable on site inventory levels, and has a fairly narrow range of standardized products. Lean production focuses on perfection- costs should be constantly decreasing, no defects are accepted, zero inventory levels and almost endless product variety. Understandably, reaching absolute perfection might never be possible. Nevertheless, it implies stepping on the path of continuous improvement and learning which is vital in nowadays constantly changing business environment. Adoption of lean thinking imposes learning, personal development since it involves all employees and workers are involved and responsibility is pushed down the organizational ladder. Even line workers become aware that their mistakes might slow down the whole production system therefore, tasks are done with greater attention and mistakes are corrected right away (Shell, 2009).

Lean as a concept has been evolving over time and therefore its deeper understanding might be somewhat complicated. Hines et al. (2004) emphasize the important fact that for the right understanding of lean thinking it is crucial to realize that becoming lean is not solely about cutting costs. It is rather about creating value for the customer. Nevertheless, the essential concept of muda (waste) refers to everything that does not add value to the product. Muda is something that customer is not willing to pay for and therefore should be eliminated. Moreover, Hines et al. (2004) state that in the end it is the customer who decides what muda is and what is not. In summary, it is essential to understand that the blind focus on cost-cutting cannot be considered lean.

Customer value, in simplest words, means the difference it between what a customer is paying for a product (plus the time and effort spent on acquiring it and learning how to use it) and what he or she is getting in return, e.g. product features quality and service. Maximizing customer value is about maximizing the difference with the two aforementioned dimensions. Lean philosophy will focus on creating more value for the customers with fewer resources. Lean ultimately aims at creating perfect value to customer through a perfect and zero waste value creation process.

Still, the idea of waste elimination is the backbone of the lean philosophy. According to Karlsson and Åhlstrom (1996) waste is generated by various sources. Inventory is probably the most important one. According to lean thinking keeping parts and products in stock does not add any value to them and therefore should be eliminated. Inventory of work in progress is perceived a particularly expensive form of muda. Nevertheless, the reduction or elimination of inventory should be well thought through. The authors suggest focusing on the reason for inventory's existence. This could be achieved by reducing lot sizes and set up-times (SMED) or minimizing down time in machines.

According to Karlsson and Åhlstrom (1996) another important source of muda is transportation of parts from one location to another in the factory. The problem of transportation needs to be examined to distinguish between rationalization of transportation and elimination of the need for transportation. The same applies to the time needed for gathering tools needed e.g. for the assembly process. Grouping the machines and tools in a place where they are needed is just one simple solution that allow for waste elimination.

Another important source of waste is the lack of quality. Defect parts need to be reworked and that leads to additional costs. Elimination of scrap and rework should be given particular attention. The pursuit of excellent quality is one of the most important indicators of becoming lean. Constantly improving quality is not only a goal in itself but it also needed to attain a high level of productivity since it is crucial to focus on having fault-free products from the very beginning.

Assuring highest possible quality is also achieved by assigning responsibility for quality assurance to everyone. This makes the process more effective since line workers are able and entitled to identify a faulty part, not the quality department. Line workers are even allowed to stop the line so that the error correction occurs immediately. The ingenious idea of becoming lean is therefore based on ensuring quality from the beginning.

Multifunctional teams are also very important part of lean philosophy. According to Karlsson and Åhlstrom (1996) multifunctional team is a group of employees who are able to perform many different tasks. Such teams are often organized around cell-based part of the product flow. Production process becomes faster and more effective. In the case of SMEs creating multifunctional teams might be challenging due to the fact of not having enough staff. In such case multi-functionality might be reworked in a way that it refers to every single worker. However, achieving e.g. a multifunctional line worker needs to be supported by the simplification of assembly procedures (design for assembly).

According to Achanga et al. (2005) there are several crucial factors that influence the process of lean philosophy implementation. Those factors should be taken into consideration while stepping on the path of "becoming lean". Authors name leadership and management, financial capabilities, skills and expertise and organizational culture. Therefore, it should be stated clearly that the process of lean principles adoption goes far beyond rearranging production lines and reducing inventory levels. It is beyond the scope of this document to refer to the issues of organizational culture. Nevertheless, the proposed solutions are assumed to be relatively easy to implement. Simultaneously, they can be seen as the beginning of the never ending journey towards lean.

Nowadays, lean production has evolved into comprehensive management system. Its effective implementation involves cultural changes in organization, new approaches to product and to serving customers and high degree of training and education of employees from upper management to the shop floor (Sim and Rogers, 2009).

In summary, lean philosophy is based on the idea of continuous improvement (kaizen). The pursuit of achieving perfection in every area of the manufacturing process requires the change of thinking. Companies need to go far beyond merely cutting costs wherever possible and step into the road towards perfection. It is crucial to understand and bear in mind that becoming lean is not a project- it is a journey that requires a change of mindset. Therefore, once becoming lean is decided there is no end date. Moreover, according to Yamamoto and Bellgran (2010) no lean transformation can take place without establishing the culture of continuous improvement and organizational learning. Lean seen as a change of mindset and organizational culture requires a long-term commitment. To really start pursuing a lean philosophy a middle-sized company would need about 3-5 years (Bhasin and Burcher, 2006).

2.1.1 Lean implementation prerequisites

According to Black (2007) lean manufacturing implementation will require time and commitment at all organizational levels from line workers to top management. Therefore, companies should be prepared to make a considerable effort before they can benefit from the introduction of lean.

The author suggests that the process of implementing lean production should concern all levels in the plant. Every single employee need to be aware of what kind of changes are going to happen and what the reasons for their implementation are. That considerably facilitates the process of becoming lean. The involvement of top management is crucial in terms of understanding and justifying the financial decisions. In general, every person in the organization must be trained to understand the idea of waste and be able to eliminate it. Moreover, the line workers should be given the responsibility of e.g. stopping the production lines whenever there is a production error. With time and growing experience line workers they should be assigned more responsibility.

Black (2007) also emphasizes the importance of choosing the right and measurable parameters that would allow for effective progress tracking in the process of lean thinking adoption.

The author also highlights the importance of motivating people and appreciating progress they make.

2.2 Design for manufacturing

Shorter time to market and customer focus are the two most important principles guiding the process of product concept creation. Therefore, the emphasis must be put on the ease of manufacturing and assembly that needs to be taken into account already at the design phase.

The design for x is a general idea that guides the product development process. The process of a concept boat development was guided by design for manufacturing and design for assembly. According to Ulrich and Eppinger (1995) there are several principles which apply to methodologies for achieving design for x. Those are as follows:

- Detail design decisions can have substantial impact on product quality and cost
- Development teams face multiple goals that are often conflicting
- It is important to have “reference points” with which to compare alternative designs
- Dramatic improvements often require substantial creative efforts early in the process
- A well-defined methodology assists the decision-making process

According to Ulrich and Eppinger (1995) manufacturing cost is a key to the economic success of a product. Therefore, economically successful design is about ensuring high product quality while minimizing manufacturing cost. Design for manufacturing methodology is a mean of achieving this goal. When implemented correctly, it should lead to low manufacturing costs without compromising product quality.

The overall DFM process consists of the following steps as suggested by Ulrich and Eppinger (1995):

- Estimation of the manufacturing costs
- Reduction of component costs
- Reduction of the assembly costs
- Reduction of the costs of supporting production
- Considering the impact of DFM decisions on other factors

In the case of this specific project an alternative and promising manufacturing technique has been identified first. The detailed analysis of manufacturing costs and lead times as well as assembly times brought a conclusion that the manufacturing technique of rotational molding will be the starting point that will guide the further design activities.

2.3 Industrial design

In the process of creating a final product concept the idea of industrial design played a significant role. According to Ulrich and Eppinger (1995) industrial design is “*a professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer*”. There are several critical goals that should be achieved when developing new products and industrial design is intended to support the process of achieving them. The goals are as follows:

– Utility (product’s human interfaces should be safe, easy to use, and intuitive; features should communicate their functions to users through shape)
– Appearance (form, line, proportions and color are utilized to integrate the product into a pleasing whole)
– Ease of maintenance (product design must communicate how the products are to be maintained and repaired)
– Low costs (careful planning of forms and features as they have large impact on tooling and production costs)
– Communication (product design should communicate the corporate design philosophy and mission through the visual qualities of the product)

In the process of concept boat creation particular attention was given to the following factors: utility, ease of maintenance and low costs. This approach will be justified in the following chapters.

2.4 Rotational molding

The concept boat is intended to be a product of rotational molding which currently grows in popularity due to being relatively fast and giving designers span for their creativity. According to Association of Rotational Molding (1999) there are the following phases of rotational molding:
– Loading of the predetermined amount of plastic in powder or liquid form into the mold and closing the mold
– Biaxial rotation of the mold inside an oven
– Melting of plastic and formation of coating over the inside of the mold
– Removing the mold from oven and cooling
– Opening the mold and removing the hollow part

The main advantages of rotational molding are as follows:
– The possibility to manufacture small or large parts even as one piece (basically a whole boat could be rotationally molded as one piece
– The possibility to have rotationally molded pieces with variable wall thicknesses (although the differences in thickness should not be too big)
– The ability to produce large and complex parts in relatively short time
– The mold investment can be costly, nevertheless costs of manufacturing can be saved as a consequence

– Rotationally molded parts are resistant to corrosion and cracking
– The wide array of possible surface finish (rough, smooth, embossed, etc.)
– The possibility to have inserts or integrally molded in threads
– Almost no material wastage
– Different types of products can be molded together in one machine

Limitations of rotational molding comprise of:

– Difficulties with achieving large flat parts (especially important in the case of rotationally molded deck platform; large flat parts require special rotational molding techniques)
– Difficulties with achieving high- tolerance parts
– Long molding cycles
– High heat expansion
– Only a limited number of resins can be successfully processed

Rotational molding offers a possibility to take boat manufacturing to a “higher level”. The aforementioned conditions force companies to take steps towards improvement and leveraged efficiency. Rotational molding is an opportunity to achieve both. Moreover, this manufacturing method eliminates the problem of harmful substances elimination. Therefore, it is an interesting alternative to e.g. spray lamination which proves to be dangerous for both people and environment.

3 PRODUCT DESIGN

3.1 Product platform and variants development

Based the product concept generation was an additional aim of the project. According to Ulrich and Eppinger (1995) products built on technology platforms are much simpler to develop than if the technology were developed from scratch.

From a broader perspective described by Muffato (1999) product platform can be defined as a collection of assets shared by a relatively large set of product components that are physically connected as a stable sub- assembly and are common to different final models.

According to Muffato (1999) the main reasons for platform development are:
- cost reduction
- efficiency and productivity of product development
- development lead time reduction

In the particular case of this project, platform development was not a cost-intensive and time consuming activity. Based on the results of segmentation in was clear that the target groups are not expecting revolutionary solutions or a total breakthrough in the understanding of the boat concept. Instead, smart solutions allowing for considerable cost reductions were needed. Therefore, the three boat models were proposed, each of them based on the same hull concept.

The challenge of implementing the product platform development concept during the product development process was the definition of the scope of a platform. Finally, it was agreed that the final understanding of common platform will comprise of the following:
- rotationally molded hull (with kiss- offs that allow the pre-installation of cables and fuel tank)
- rotationally molded deck plate
- steering console
- benches
- storage boxes

The focus here is put on the platform parts that can be rotationally molded. Table 3 presents the sample division into rotationally molded and purchased boat components:

Table 3. Rotationally molded and purchased boat components

Rotationally molded components	**Purchased components**
- Hull - Deck plate - Steering console - Passenger console - Seats - Boxes with lids - Fuel tank - Swimming ladder	- Side rails (aluminum) - Front rail (aluminum) - Windshield - Battery cover - Bilge pump - Steering devices - Steering wheel - Side lights - White 360 ° light - Light pole for white light

The differences between the proposed boat models will be achieved with the installation of the upper part as well as with different design and location of pulpit. For the clarity of understanding and ease of further analysis the focus will be put at the common parts that can be rotationally molded.

The idea of product platform is based upon the assumption that there are three versions of a boat that will be manufactured in a concept factory. The variants are as follows:

Basic (open boat)

A simple boat model intended for leisure, fishing, etc. A versatile model. Includes (in its most simple format) a row of seat/storage boxes, two swivel chairs and two pulpits: steering pulpit and passenger pulpit (both including windscreen).

Console (center console)

A more refined model, built on the lines of a speedboat, suitable for leisure and sport. In its simplest format it includes a row of seats/storage boxes, two swivel chairs and a larger central console, for added wind cover and for that walk around model look.

Covered

The luxury model, closely mimicking the appearance of a much bigger and more costly boat. In its simplest format it includes a row of seat/storage boxes, two swivel chairs and a covering superstructure providing excellent protection for the elements.

3.2 Product concept

The overall product concept is based on the results of the segmentation process. The segmentation process was conducted as a part of a different project that preceded the product development activities. The aim of the segmentation process was to outline the customer groups that can be found among the Finnish recreational motor boaters. According to Pekkala and Peltonen (2010) particularly important were the attitudes towards boating, lifestyle, psychographics and motivation for boating. Those were the starting points in the process of segmentation. The following customer groups were outlined in the segmentation process:

- Family boaters (boating is a good way of spending time together with family, this group values comfort and convenience on board)
- Relaxing fishers (boating is a good opportunity to spend time alone, and boat is a perceived as a tool for fishing)
- Cottage boaters (boat is a mean of travelling to cottage, and cottage boaters only sail in familiar areas)

In the process of segmentation, additional two groups were identified- forerunners and brand conscious customers. Those two groups differ considerably from the aforementioned and were put into category of dedicated boaters. Dedicated boaters spend a significant part of their free time on boat or on activities related to boating. They appreciate professional boat features since they enjoy boating in challenging conditions.

The focus of the project is on two groups: relaxing fishers and family boaters. Their preferences and expectations guide the product development process.

Based on the segmentation results several guiding principles for product concept creation were outlined. The following keywords summarize the segmentation process:
- customizable
- low price
- ease of maintenance (especially when it comes to cleaning)
- ease of maneuverability (hull that tolerates hitting, ease of steering)
- big storage space
- safety
- low level of status (boat is not a mean of displaying material status)
- accessibility (getting onboard as well as getting off the boat should be as easy as possible)
- ease of docking

Another important principle guiding the design process was the idea of having as many functionalities in one component as possible. According to Shamsuzzoha et al. (2010) there should be a link between external varieties which evolve from customer preferences, market demands, etc. and internal varieties such as list of components, products performance and quality. To illustrate the objective of having as many functionalities in the same component, Table 4 has been outlined:

Table 4. Components and functionalities

Components	**Functional elements**
deck	safety “child-friendliness”
hull	balance (walk- around possibility) durability
rails	ease of docking safety walk-around possibility
console	walk-around possibility ease of driving good visibility
container	equipment protection walk-around possibility
roof	protection of passengers and equipment additional energy harvesting possibility (solar battery) visibility attractive design
windows	visibility attractive design

The underlying idea is to minimize the number of components without compromising the functionalities valued by the outlined target groups of relaxing fishers and family boaters. Figure 1 presents the evolution of the concept:

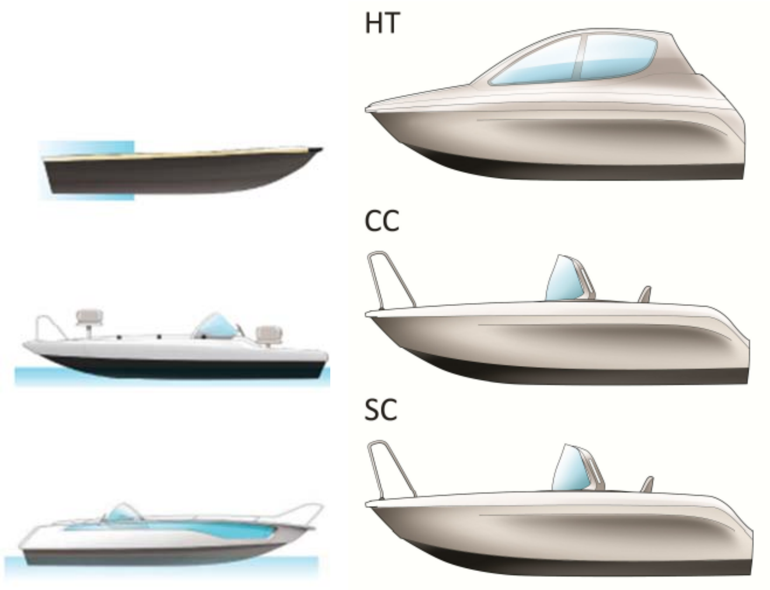

Figure 1. Boat concept evolution

From very basic open boat to more fancy but yet low priced and maintaining the desired low level status. The initial drafts on the left-hand side evolved into the final concept presented on the right-hand side. The final concept comprise of the following three boat models:
– hard top (covered model)
– center console (steering console located centrally)
– side console (steering console located at the side)

The justification of the presented design stems from the segmentation process as well as the identification of the key customer requirements.

The selection of rotational molding as a manufacturing method brought a lot of additional benefits for the product creation. First of all, the rotational molding of the boat hull makes the structure ribbed (kiss-offs). The rows in the hull surface allow for pre-installation of cables, bilge pump, fuel pipes or even a fuel tank, before the rotationally molded deck is installed.

Moreover, rotational molding offers the possibility of molding in metal inserts that enable quick, almost snap-on installation of e.g. upper part of a boat. Figure 2 presents the idea of having metal insert rotationally molded into the plastic structure. In that particular case inserts are placed on the ridges of the hull so that the upper part can be installed almost in no time.

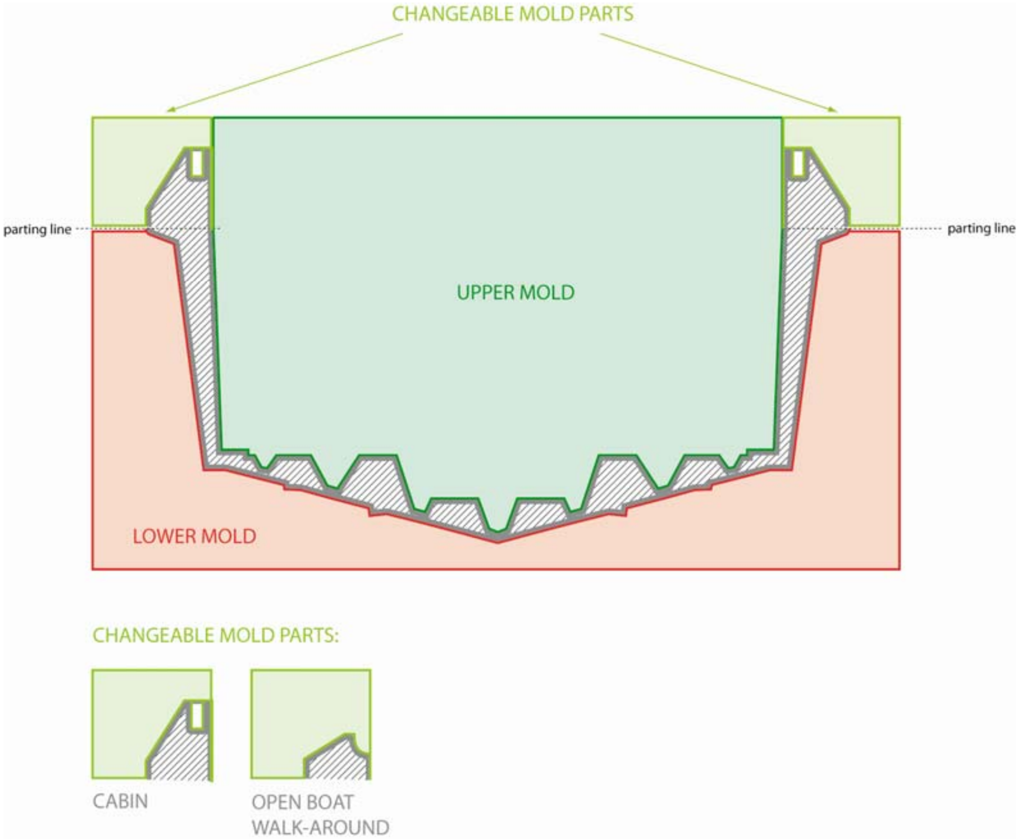

Figure 2. Rotational molding for quick assembly

Another innovative idea is the installation of the aluminum profile in the kiss-off ribs. The aluminum profile is a lightweight solution that allows for customization of seats, steering consoles (pulpits) and storage boxes. Figure 3 illustrates the idea of a built-in aluminum profile.

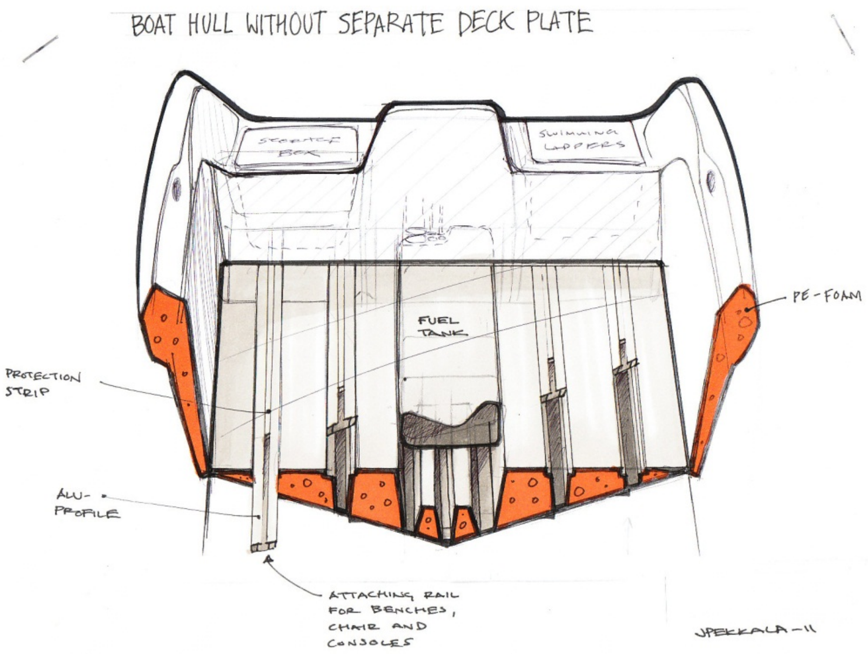

Figure 3. Built-in aluminum profile

Yet another interesting concept that might be adopted by the boat manufacturers is the possibility to having the whole boat rotationally molded as one piece. Even though the manufacturing of a boat as one piece is not the case of this project it unveils even more possibilities of significant cost-cutting.

An interesting concept proposed is the possibility of having the rotationally molded swimming ladder which is a step towards improved boat accessibility. Figure 4 presents the idea of rotationally molded swimming ladder.

Figure 4. Rotationally molded swimming ladder

4 FINANCIAL JUSTIFICATION OF ROTATIONAL MOLDING

4.1 Bill of materials

Bill of materials in its simplest form is a list of components needed for manufacturing of the end product. Table 5 presents the bill of materials for a rotationally molded motor boat (boat engine is excluded from the calculations).

Table 5. Bill of materials

	Material costs – Rotationally molded hull, accessories, additional			
	ALV 0%			
Part	**Measurements / Details**	**pcs**	**€/pcs**	**€/total**
Hull	ca. 30 m2	1	1000	**1000**[1]
Deck plate	Rotomolded	1	240	**240**
Superstructure	Rotomolded, incl. Windscreens, wipers, door	1	400	**400**
Center console	Rotomolded, incl. Windscr., gauges, switches	1	280	**280**
Driver's pulpit	Rotomolded, incl. Windscr., gauges, switches	1	160	**160**
Passenger's pulpit	Rotomolded, incl. Windscreen	1	92	**92**
Seat(s)	Rotomolded	2	20	**40**
Seat foundati-on	2 pcs.	2	33	**66**
Swimming ladder	Stainless steel pipe, d 20 mm	1	18	**18**
Windscreen	Included in pulpits	2	-	**-**
Deck storage boxes	Rotomolded	3	56	**168**
Cleat	Stainless steel 6-20 €, rubber 2-3 €	4	3,6	**14,4**
Fuel tank, assy.	Rotomolded, 50 L	1	40	**40**
Battery casing	Plastic	1	5,4	**5,4**
Bilge pump	13-25 €	1	6	**6**
Steering pulpit acc.	Included in pulpit	-	-	**-**

[1] The final hull price might vary depending on wall thickness and entrepreneur's profit margin.

Side light(s)		2	3	**6**
360 drive light	Incl. Antenna	1	6,9	**6,9**
Drive light antenna	Included in 360 drive light	1	-	**-**
Cap, fuel tank	50 mm	1	2,1	**2,1**
Eye bolt	Stainless steel pipe	1	1,8	**1,8**
Rear railing	ca. 2m, RST pipe, d 25 mm	1	-	**-**
Side railing(s)	Stainless steel pipe, d 24 mm, 3000 mm, no endplugs	2	-	**-**
Front railing	Stainless steel pipe, d 24 mm, 2500 mm	1	-	**-**
Railings, assy.	Rear railing, side railings, front railing	4	-	**30**
Accessories/mandat.	Safety vest, paddle, bilge scoop, fire ext.	-	-	**36**

Total material costs are summarized in Table 6:

Table 6. Total material costs

Basic	**Console**	**Covered**
1933 €	1960,6 €	2240,6 €

4.2 Rotational molding investments

Rotational molding of large items such as boat components requires an oven-model machine. Certainly, it is more flexible and efficient to produce smaller components such as boxes, seats and pulpits in a separate machine that requires smaller molds. Nevertheless, it is possible to produce a set of smaller components in a larger machine while utilizing the DFA (design for assembly) approach that aims at considering the mold count already at the design stage which aims as its minimization.

According to information provided by the local rotational molding company the cost of large rotational molding machine is around 500 000- 600 000 €.

Table 7 presents molds necessary to produce the aforementioned three boat models:

Table 7. Rotational molding investments

component	pieces	cost	total
hull	1,5	65 000 €	95 000 €
deck plate	1	35 000 €	35 000 €
steering/passenger pulpit	2	45 000 €	90 000 €
center console	1	50 000 €	50 000 €
superstructure	1	50 000 €	50 000 €
box	3	20 000 €	60 000 €
fuel tank	1	20 000 €	20 000 €
chair	2	20 000 €	40 000 €

The total cost of molds is 440 000 €.

4.3 Assembly stages and time consumption breakdown

The assembly process refers to the activities that take part after the part has been rotationally molded, taken away from the mold, cooled down and tested for faults. The process of putting together rotationally molded parts as well as the attachment of purchased components is the assembly process. Table 8 presents assembly stages for basic and console boat models:

Table 8. Assembly stages for basic and console models

	Assembly stages - Basic & Console models			
Operation	**Assembly**	**Time (min)**	**Re-peats**	**Total time (min)**
Install	**Fuel tank assembly**	10	1	**10**
Install and test	**Bilge pump**	10	1	**10**
Insert & Attach	**Deck plate**	80	1	**80**
Attach & Connect	**Driver's pulpit (inc. steering etc.)**	100	1	**100**
Attach	**Passenger's pulpit**	32,5	1	**32,5**
OR				
Attach & Connect	**Center console (inc. steering etc.)**	100	1	**100**
Attach & Connect	**360 drive light (inc. antenna)**	15	1	**15**

Attach & Connect	**Battery casing**	7,5	1	**7,5**
Attach & Connect	**Side light(s)**	15	2	**30**
Attach	**Seat foundation**	10	2	**20**
Attach	**Deck storage boxes**	7,5	3	**22,5**
Insert & Attach	**Seat(s)**	7,5	2	**15**
Attach	**Rear railing**	10	1	**10**
Attach	**Side railings**	12,5	2	**25**
Attach	**Front railing**	10	1	**10**
Attach	**Eye bolt**	5	1	**5**
Attach	**Cleats**	2,5	4	**10**
Insert & Attach	**Swimming ladder**	7,5	1	**7,5**
Install	**Cap, fuel tank**	2,5	1	**2,5**
Add	**Accessories, obligatory**	17,5	1	**17,5**
Add	**Stickers & Emblems**	5	4	**20**
	After-assembly tests	90	1	**90**

Total assembly time for basic model: 9, 00 man-hours

Total assembly time for console model: 8, 46 man-hours

Assembly stages with time consumption data for covered model are presented in Table 9:

Table 9. Assembly stages for covered model

	Assembly stages - Covered model			
Operation	**Assembly**	**Time (min)**	**Repeats**	**Total time (min)**
Install	**Fuel tank assembly**	10	1	**10**
Install and test	**Bilge pump**	10	1	**10**
Insert & Attach	**Deck plate**	80	1	**80**
Attach & Connect	**Driver's pulpit (inc. steering etc.)**	100	1	**100**
Attach & Connect	**360 drive light (inc. antenna)**	15	1	**15**
Attach & Connect	**Battery casing**	7,5	1	**7,5**
Attach & Connect	**Side light(s)**	15	2	**30**
Attach	**Seat foundation**	10	2	**20**
Attach	**Deck storage bo-**	7,5	3	**22,5**

	xes			
Insert & Attach	**Seat(s)**	7,5	2	**15**
Insert & Attach	**Superstructure**	90	1	**90**
Attach	**Rear railing**	10	1	**10**
Attach	**Side railings**	12,5	2	**25**
Attach	**Front railing**	10	1	**10**
Attach	**Eye bolt**	5	1	**5**
Attach	**Cleats**	2,5	4	**10**
Insert & Attach	**Swimming ladder**	7,5	1	**7,5**
Install	**Cap, fuel tank**	2,5	1	**2,5**
Add	**Accessories, obligatory**	17,5	1	**17,5**
Add	**Stickers & Emblems**	5	4	**20**
	After-assembly tests	90	1	**90**

Total assembly time: 9,96 man-hours

Table 10. Assembly costs for three boat models

Assembly costs						
	Basic		**Console**		**Covered**	
Fuel tank assembly	4,75	€	4,75	€	4,75	€
Bilge pump	4,75	€	4,75	€	4,75	€
Deck plate	38	€	38	€	38	€
Driver's pulpit	47,5	€	-		47,5	€
Passenger's pulpit	15,4375	€	-		-	
Center console	-		47,5	€	-	
360 drive light	7,125	€	7,125	€	7,125	€
Battery casing	3,5625	€	3,5625	€	3,5625	€
Side light(s)	14,25	€	14,25	€	14,25	€
Seat foundation	9,5	€	9,5	€	9,5	€
Deck storage boxes	10,6875	€	10,6875	€	10,6875	€
Seat(s)	7,125	€	7,125	€	7,125	€
Superstructure	-		-		42,75	€
Rear railing	4,75	€	4,75	€	4,75	€
Side railings	11,875	€	11,875	€	11,875	€

Front railing	4,75	€	4,75	€	4,75	€
Eye bolt	2,375	€	2,375	€	2,375	€
Cleats	4,75	€	4,75	€	4,75	€
Swimming ladder	3,5625	€	3,5625	€	3,5625	€
Cap, fuel tank	1,1875	€	1,1875	€	1,1875	€
Accessories	8,3125	€	8,3125	€	8,3125	€
Stickers & Emblems	9,5	€	9,5	€	9,5	€
After-assembly tests	42,75	€	42,75	€	42,75	€
	Sum, work 256,5		**Sum, work 241,1**		**Sum, work 283,8**	

Salary cost has been calculated on an average wage rate of 28,5 € which includes approximately 30 % social costs.

4.4 Rotational molding lead times

Table 11 presents lead times for rotational molding of boat components. These lead times do not need to be added to total work time because:

- They are included in parts costs
- Machine can be operated alongside assembly operations
- Machine requires very little attendance

Table 11. Rotational molding lead times

	Baking	**Molding/demolding**	**Cooling**	**Total**
bigger parts(hull, deck plate, superstructure)	45 min	15 min	40 min	**100 min**
smaller parts(steering/passenger pulpit, center console, box, chair)	15 min	10 min	20 min	**45 min**

4.5 Costs in total

The summary of production costs is presented in Table 12.

Table 12. The summary of production costs

			
material costs	1933 € (39% of sales price)	1961 € (39% of sales price)	2241 € (43 % of sales price)
assembly costs	257 € (5% of sales price)	241 € (5% of sales price)	284€ (5% of sales price)
total	**2189 €**	**2202 €**	**2524 €**

Table 13 presents the investment payback. The assumption is that if 250 boats are sold per year the investment costs of molds and machinery (amortized) are as presented in the table. Percentages in brackets indicate the share of material and assembly costs in the overall sales price (given in Table 14).

Table 13. Investment payback

			
+	586 € (12% of sales price)	586 € (12% of sales price)	586 € (11% of sales price)
total	**2775 €**	**2788 €**	**3110 €**

Expected profit at a given sales price is presented in Table 14.

Table 14. Expected profit at a given sales price

			
sales price	5000 €	5000 €	5200 €
-	2775 €	2788 €	3110 €
total	**2225 €** (44% of sales price	**2212 €** (44% of sales price)	**2090 €** (40% of sales price)

Figure 5 presents the comparison of rotational molding and spray lamination methods in terms of production costs.

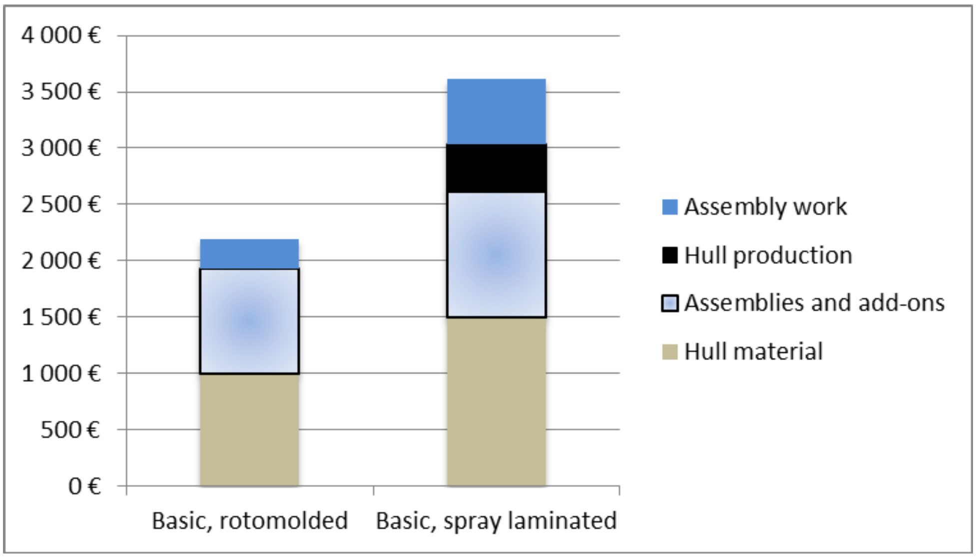

Figure 5. Production costs compared- rotational molding and spray lamination

Figure 6 presents the costs structure with the assumption that 250 boats are produced per year.

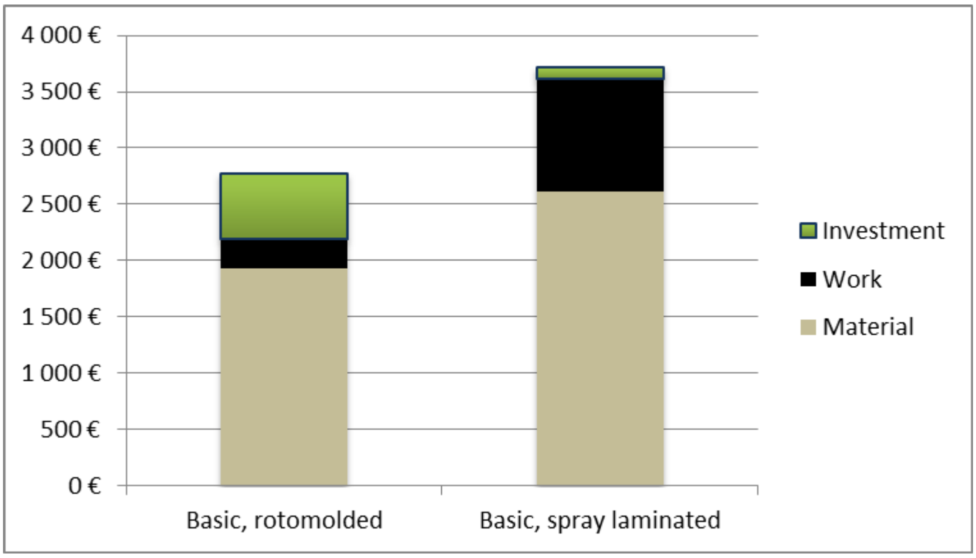

Figure 6. Costs structure for rotationally molded and spray laminated boats

Figure 7 shows the break-even point for the outsourced production when only investment in molds is needed.

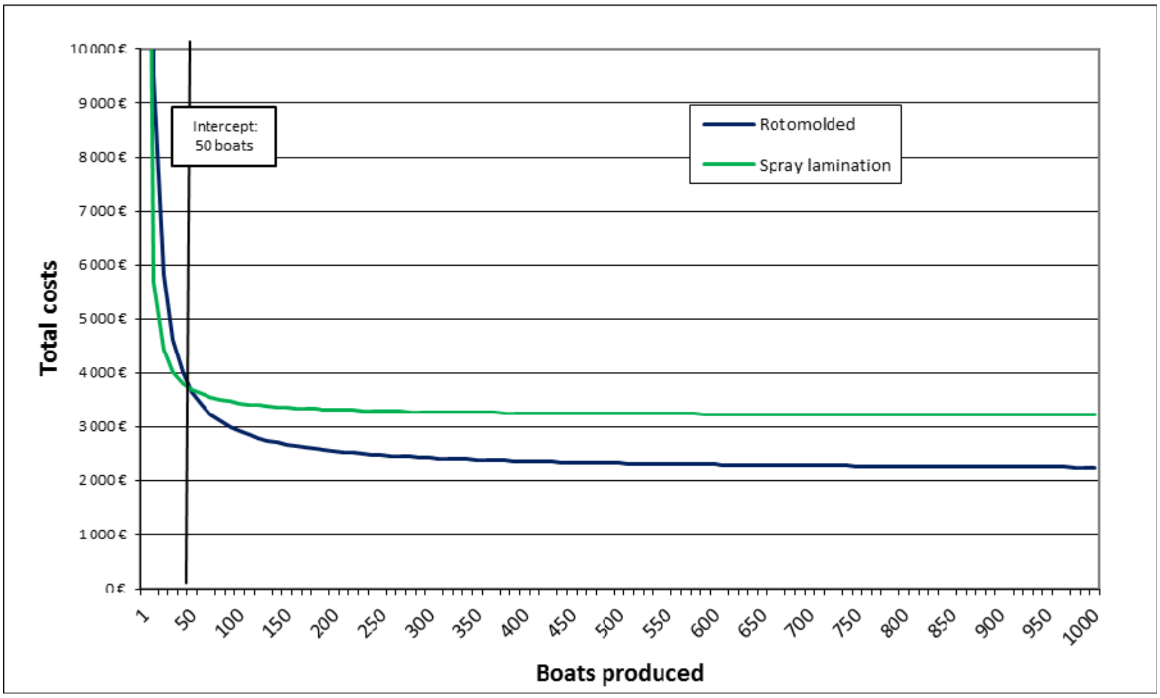

Figure 7. Break-even point for the outsourced production (mold investment needed)

Figure 8 shows the break-even point in the case when both machinery and molds investments are required.

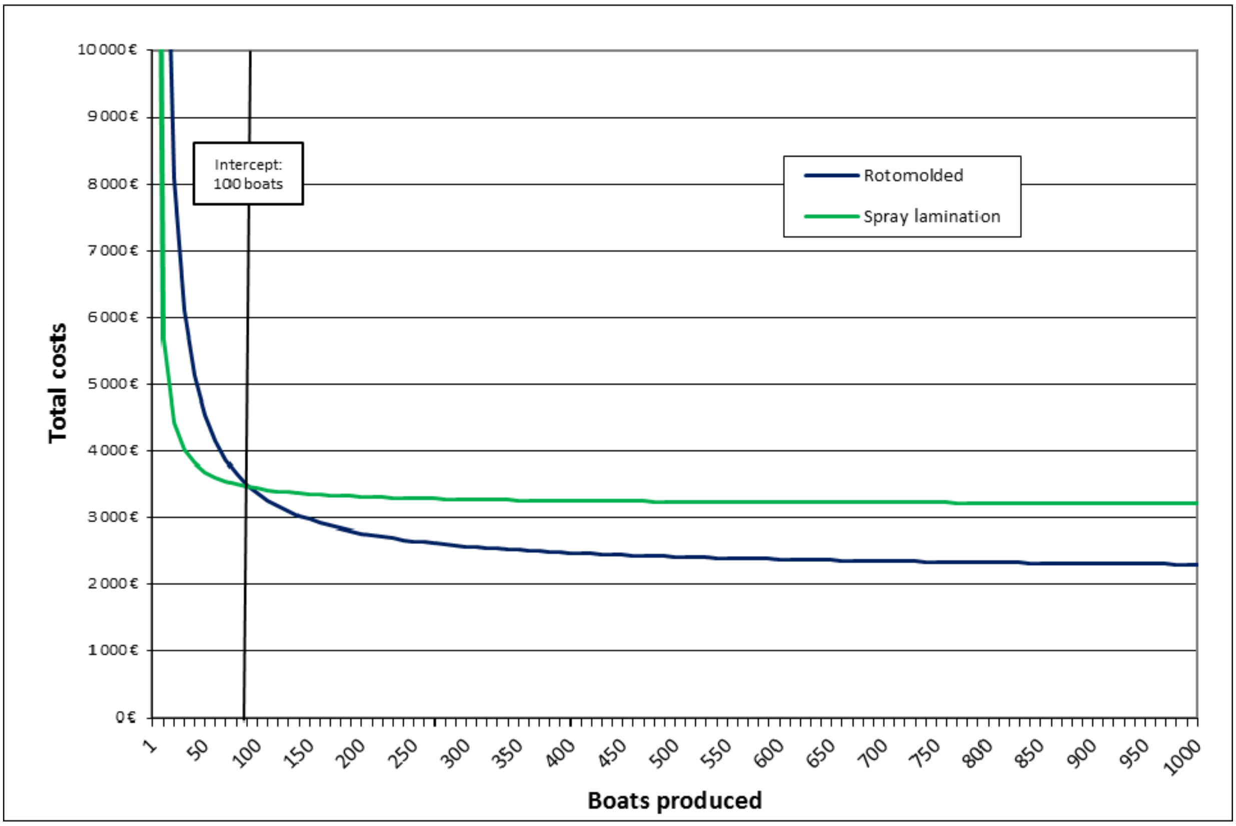

Figure 8. Break-even point (machinery and molds investments are needed)

5 LEAN FACTORY

5.1 Factory layout

According to lean philosophy lean factory layout should be easy to visualize. That makes the layout simple and easy to follow and is believed to be more efficient in terms of material flow. Simple floor layout is easy to understand for line workers and it makes bottlenecks and any other problems quickly visible. This implies that they can be corrected straight away. Implementation of techniques such as 5s is known to be one of the most effective ways of driving a lean flow. The closest to perfection factory layout should realize the following:

- Product-focused work cells
- Focused plant-within-plant factories
- Reduced storage and handling space
- Kanban stock points
- Direct delivery of raw materials
- Integrated support areas

The proposed factory layout for rotationally molded concept boat relays on the idea of cellular manufacturing. Cellular manufacturing system refers to such factory layout that allows for smooth flow of inventories and materials that produce the final product. The aim is to reduce the transport of parts, waiting time as well as to avoid delays in production process. Cellular manufacturing requires elimination of bottlenecks along the single process flow as well as the introduction of pull system. Pull system is based on the rule that required inventories and materials should be requested (in other words “pulled in”) by each station from the station preceding it. The proposed factory layout aims at getting benefits from cellular manufacturing and pull system. The circular factory layout and implementation of kanban system are the proposed means of achieving higher production efficiency, elimination of waste, reduced inventory levels, most effective use of floor space, shorter production cycle times, and improved customer response time as a consequence.

The previously described idea of a concept boat is a crucial starting point for a concept factory planning as it determines its layout and flow of activities. The overall assumptions guiding the conceptualization of a lean boat factory of the future are the following:

- Shortening manufacturing times
- Faster time to market
- Reduction of manufacturing costs

– Simplification of the assembly process

The factory of the future should be driven by lean principles. Therefore, the following concepts will be implemented and explained in more detail:
– SMED (single minute exchange of die)
– Kanban
– 5 S
– Design for assembly (aiming at simplifying the whole assembly process)

The factory layout is one of the most important decision requiring detailed planning and careful considerations since once a decision is made and introduced the costs of changing the layout might be tremendous. According to Allington (2006) there are three basic layout types to choose from:
– Process layout where similar manufacturing processes are grouped together to improve utilization
– Cell layout where materials and information entering are initially divided into groups in order to move to a specific part of the operation (a cell). Parts are then processed within those cells in sequential order. Cells are designed to moderate the complexity of flow which is characteristic to process layout
– Product layout which involves arranging the machines and equipment in a way that reflects the sequence required by product

Having in mind the specifics of rotational molding it seems that the optimal solution would be the application of product layout.

The proposed factory layout is based on the characteristics of rotational molding machine which usually is a bulky object that requires space. The machine needs to be given a fixed place within a plant since once placed cannot be moved so easy. Therefore, the concept factory layout puts rotational molding machine in the beginning of the manufacturing process. Operations based on semicircular or circular layout are intended to enable:
– Quick inserting of plastic powder
– Quick exchange of molds (if needed)
– Quick removal of ready components
– Ease of storing those molds that are not being used
– Ease of moving to further assembly stages

Length of this cycle is determined mostly by the required baking time. Since rotational molding machine once running requires little or no attendance, factory workers are able to complete other tasks in the same time. By installing a visible countdown timer above the machine workers are able to immediately assist machine operations. Such organization of manufacturing is expected to be less time consuming and more effective.

After a component has been rotationally molded and removed from mold it will be left for cooling (for a certain amount of time depending on its size). Once a part has cooled down it will be scanned for faults. Scanning the part will allow for the quick identification of e.g. deviations from desired wall thickness. The idea of the “boat scanner” is based on laser checking for cracks, voids as well as controlling thickness. If the part is considered faulty it will be recycled in order to turn it back into plastic powder. In the case there are no faults in component the assembly process can begin.

Assembly process comprises of putting rotationally molded parts together as well as installing additional elements that mostly have been purchased beforehand. The assembly process should be as short as possible. The proposed techniques, tools and methods for reaching that state will be described in more detail in following chapters.

After the assembly process has been completed a boat is given a barcode that enables its tracking by a dealer. Finished boat will be transported to a customer in order to avoid waste of valuable storage space.

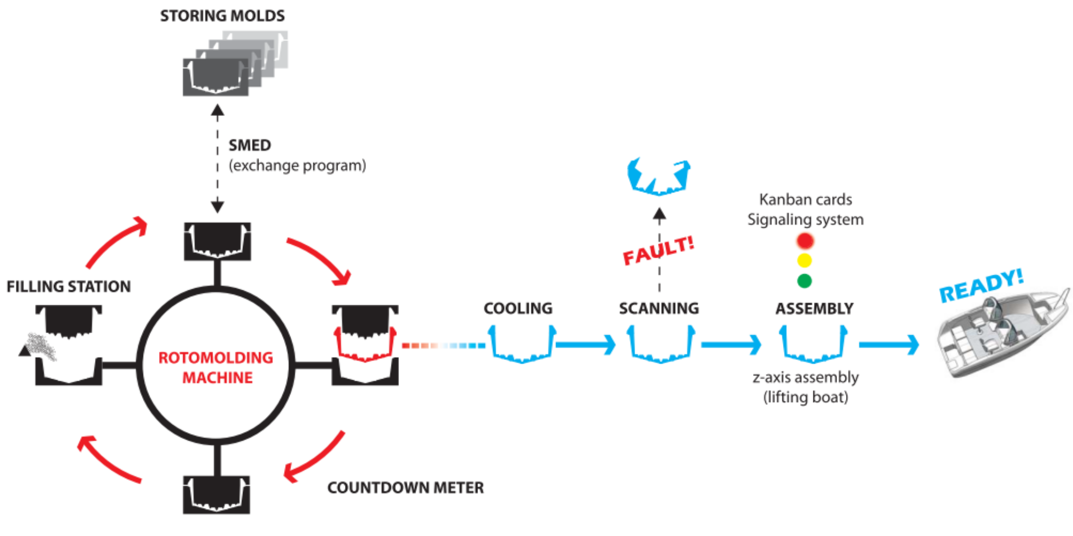

Figure 9. Concept factory layout

The proposed factory layout- product focus based on a common assembly line is justified by the following:

– Manufactured product can be classified as one product family (the differences between versions does not require totally different assembly processes)

- Manufactured products require uniform transportation methods be-tween assembly stages (e.g. omni- wheels platforms)
- Manufactured products are characterized by components commonality- no significant differences in storage space required for components
- Commonality of tools required for the assembly process

Therefore, a factory that produces three product variations belonging to the same product family should be considered focusing on product rather than on process.

5.2 Methods and tools

According to Appleton and Garside (2000) the ease of assembly is widely known to be determined at the design stage. The estimation and determination of assembly costs should be taken into consideration as early as possible. In practice, it means the designing stage where all the changes are fairly easy to be made since the product is not manufactured yet.

The basic step towards achieving the effective design for assembly is carefully planning the parts. The efficient assembly requires as little parts as possible and there are several methods that foster the parts reduction.

Reduction of part count and usage of components that provide quick assembly should always be the guiding rule for designers. In the case of boating industry, rotational molding offers an opportunity to decrease number of parts. Namely, the whole simple open boat can be rotationally molded as one piece. However, such a boat does not offer any span for customization and gives customers very little or no freedom of choice. Therefore, solutions like rotationally molded inserts which make quick snap-on installation possible. Additional solutions are as follows:

- installation of fuel tank and fuel pipes under the deck plate-n o need to climb on boat
- installation of consoles, steering devices, boxes and cables on a deck plate- no need to climb on boat
- deck plate with ready installed components is lifted and fastened to the hull

When the challenge of finding the optimal number of parts has been resolved there is still the need for a practical approach to the actual assembly process. Taking into consideration the above mentioned ways of maximizing the ease of assembly the following solutions have been suggested:

- Reduction of parts number- rotational molding makes it possible to have a simple boat molded as one piece.

- Reduction of screws and other items that make the assembly process time consuming. Rotational molding offers the possibility of having molded in-serts that enable a simple, snap-on installation.
- Reduction of number of tools needed for assembly. The concept of "5 tools boat" where the assembly process has been well thought and resulted in assembly simplified to a degree when only a limited number of tools is required.
- Equipping each assembly worker with a special vest which can carry all the necessary tools- reduces the need for walking around in order to get the necessary tools.

Single minute exchange of die

In order to have the process of rotational molding running smoothly and continuously, single minute exchange of die can be implemented. SMED provides manufacturing process with the opportunity to quickly change the molds for having different boat components produced within shortened time. The method of single minute exchange aims at reduction of setup and adjustment times. It has been developed in Japan by Shigeo Shingo.

Practical implementation of SMED can be broken down into three following steps:

- Separation of external and internal setup

Based on the fact that certain tasks can be done when machine is operating (external) while others will require stopping the machine (internal). Tasks that can be done while the machine is running comprise of parts and tools preparation, bringing the necessary molds closer to rotationally molding machine, preparation of plastic powder, etc. By having a clear division in between those two kinds of operations, setup times can be easily reduced.

- Converting internal setup to external setup

Requires reexamining the operations that require stopping the machinery and finding the ways to have them performed wile machine is still running.

- Streamlining external and internal operations

In this stage the remaining external and internal operations should be improved. If it is impossible to eliminate the division into external and internal operations both groups should be cross checked for improvement opportunities.

Table 15 shows the sample rotational molding setup and opportunities for time savings:

Table 15. The classification of operations for SMED

OPERATION	CLASSIFICATION	IMPROVEMENT (TIME SAVING)
Choosing the right mold	external	Color coding parts and molds, mold number reduction in order to reduce the need of mold changing
Retrieving mold from storage	external	Storage space close to the rotational molding machine
Turning off the machine		
Removing the previous mold	internal	Additional person for assis-tance, cooling down area in close proximity
Installing the desired mold	internal	Selection of the right tools and minimizing their number, choosing molds with closing system as simple as possible
Inserting plastic powder	internal	Preparation of the right amount in advance
Machine check	internal	Becomes quicker with practi-ce
Turning on the machine		

In the specific case of rotational molding the division into external and internal operations cannot be banished. Nevertheless, the proposed simple improvement solutions should already lead to considerable time savings.

The practical implementation of SMED method comprises of the following solutions:

– Carefully planning (and reducing) the number of molds needed- this step should be taken into consideration already at the design stage
– Carefully planning the location of molds storage- factory layout based on grouping rotational molding facilities and activities around the machine is aimed at speeding up the process of die exchange by keeping a short distance between storage space and the machine
– Keeping molds in close proximity to the rotational molding machine
– Preparation of molds in advance (while the rotational molding machine is running)

– Reaching the most effective changeover routine should be the ultimate goal

It is important to mention that the development of rotational molding machinery offers the opportunity of changing molds without the need of stopping the whole machine. That implies further time savings and more effective utilization of machine's capacity.

Kanban system

Kanban system is based on the "pull" idea as opposed to "push" idea. "Pulling" is aimed at reducing inventory since inventory is waste. It takes up space and uses up working capital. According to lean thinking, inventory should be avoided whenever possible and the kanban system is one of the ways to achieve it. According to Lee-Mortimer (2008) kanban system is most suitable to be implemented in the process of final assembly after the introduction of cells and balancing the workload within them.

The idea behind kanban is transferring control from the beginning of the line to the end. In other, words a given operation (say, operation B) needs to control what the previous one (operation A) gives it. This is achieved with the help of kanban card which sends a clear message to the recipient: "give me …number of item…".When that is accomplished recipient should not act until the arrival of the next kanban card signaling the needed amount. Figure 9 presents the idea of kanban:

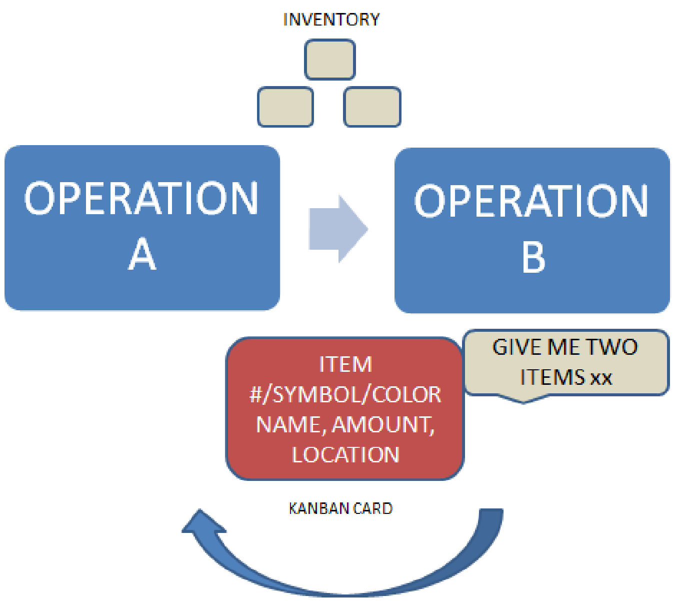

Figure 10. Kanban system

The solutions proposed for kanban system implementation in a concept factory comprise of the following:
- Estimation of inventory amount needed for the smooth flow of the assembly process
- Simplified kanban cards for the ease of communicating the need of components
- Effective and fast way of signaling the need for parts or components- e.g. visual board above each assembly stage with clearly displayed requirements. The sign triggers the setup of the rotational molding process or the retrieval of the needed parts/components from the storage space. There should be a worker with the assigned responsibility of retrieving the needed components
- Making the kanban cards visible- e.g. placing them in a special slot checked on a regular basis, having a display installed above the assembly line to make the request instantly visible

5s

According to Chapman (2005) many companies do not realize the benefits that stem from the implementation of simple procedures that aim at making the workplace cleaner and better organized. The improvements suggested by the 5s system are brilliant in their simplicity and they are not too difficult to implement. Therefore, Chapman (2005) states that the introduction of 5s should precede any other lean improvements since no serious breakthroughs can take place in a messy and badly organized workplace where employees waste time on finding and retrieving the needed parts, tools or equipment.

5 S is a Japanese method based on five keywords all starting with s. The method is aimed at achieving a cleaner and better organized workplace. According to Ho (1998) the components of 5 S are the following:
- Seiri (sorting) - in a case of organization, sorting refers to eliminating items that can be classified as rubbish. Examples of seiri application include having one set of tools for assembly, one page forms and one day processing. In other words all the materials that are not needed for completing the job should be identified. The most important benefit of sorting is freeing up the space.
- Seiton (systematize) - refers to efficiency achieved by neatness that means being able to get things fast when they are needed. In practice, planning tool layout in a way that it does not take worker too much time and effort. It also refers to the process of arranging tools and equipment in a way that promotes effective ways of working.
- Seiso (cleaning) - refers to cleaning that should be done by everyone in organization. According to Japanese way of thinking doing cleaning cleans minds

too therefore cleaning has been assigned such importance. However, cleaning goes beyond mopping and scrubbing. Smooth running of manufacturing operations can be achieved by simply making lists of responsibilities for each workplace having all assignments as clear and understandable as possible. The additional benefit of seiso is the identification of less visible problems such as leaks, breakages, fatigue or contamination.

– Seiketsu (standardization) - refers to maintaining organization’s neatness and cleanliness that can be reach by e.g. visual management. Also refers to ensuring that everyone in organization knows their role meaning that every workplace should have its precisely described
– Shitsuke (discipline) - this principle focuses on creating a workplace with good habits- teaching everyone what has to be done in what way bad ha-bits are broken and good ones are created and fostered. Discipline can be reached by practice and repetitions.

Practical implementation of 5s principles in a lean factory could comprise of the following:

– Division of assembly tools into groups and assigning them an appropriate storage space (tools used daily will be in workers closest proximity, the rest can be stored on upper shelves or in another premise)

ASSEMBLY TOOLS CLASSIFICATION			
Daily	Weekly	Emergency/repairs	Reserve
			

Figure 11. Assembly tools classification

– “5 tool vest”- aiming at reduction of tools used for assembly every day, ideally every worker would be equipped with a vest with the necessary tools attached to it so that no time is wasted on finding the right tool
– Regular examination of tools and removal of those that are broken or unnecessary

– Regular cleaning of the premises and making sure that storage spaces assigned for tools and parts are respected
– Items tagging- worker is given a freedom to tag unnecessary items with red color in order to keep the sorting process up and running
– Visual assembly guide- a well visible screen above workstations showing the assembly steps as a reference, supports the idea of flexible worker and a simplified assembly process
– Color coding of tools- each boat model has its own color assigned and tools necessary their assembly share the same color so any possible confusion during the assembly process can be avoided
– Warning lights- whenever the assembly process goes wrong or worker needs assistance he/she will be given the an authority to turn on a warning light
– Floor paint (or floor marking)- showing the direction of assembly process and indicating spaces where e.g. tool carriers should be placed or which areas should be kept empty at all times
– Auditing the implementation of 5s principles- this could be done with a simple evaluation sheet structured as suggested in Table 16:

Table 16. 5s audit sheet

AUDIT ELEMENT	**CRITERIAS**	**SCORE (0-4)**	**IMPROVEMENT SUGGESTIONS (WHO, DUE DATE)**
Parts/ components inventory	Exactly in required amount		
Tools	In place with specific reference		
Reserve tools	In place with specific reference		
Surrounding area	Free of objects that are not necessary for the work, painted where needed		
Containers	Clean, of adequate capacity, labeled		
Rubbish	No rubbish on the floor		
Signs/visual boards	Visible, in a good condition, clean		
Cleaning schedule	Cleaning according to a plan		
Excess/unnecessary materials	Identified, labeled, moved to temporary locations		
Storage space	Clean, items easy retrievable, shelves marked		

Scores from 0 to 5 mean:

0- Very bad

1- Bad

2- Average

3- Good

4- Very good

It is vital do the auditing on a regular basis so that possible weaknesses are identified, improvement ideas implemented and evaluated.

6 SUMMARY

In constantly changing business environment and erroneously traditional boat industry the drive for solutions that would be more effective in terms of cost and time is inevitable and in many cases necessary for company's survival. Therefore, the ideas presented in this handbook are based on real- business challenges that every manufacturer has to face at some point.

The backbone of the proposed solutions is the method of rotational molding fairly new for the boating industry in Finland. Rotational molding is an opportunity to reach higher production volume in less time and with fewer costs. Moreover, it is a more environment friendly solution since it produces no harmful fumes.

The choice of rotational molding dictates the proposed factory layout. Rotational molding is a fast process as compared to e.g. spray lamination, and it requires little attention. Nevertheless, the machinery investment is considerably big as well as the size of the machine. Therefore, an idea of circular layout was proposed. Putting the rotational molding machine in the center was also aimed at shortening the setup times and quick exchange of molds whenever needed.

Reduction of costs is additionally supported by increasing plant's effectiveness and elimination of waste whenever possible. Therefore, Japanese manufacturing techniques (SMED, kanban, 5 s) were proposed. Moreover, the guiding concept that stems from thinking "lean" is simplification of all processes. While operating the rotational molding machine is fairly uncomplicated the assembly process is more of a challenge. Fortunately, the ease of assembly can be achieved already at the design stage by taking into consideration the assembly process. That is why the ease of assembly was a guiding rule during the design process of presented boat models.

In summary, the biggest advantages of proposed solutions are as follows:
- The possibility of cost reduction
- The possibility of lead time reduction
- Achieving variety with one basic platform
- Simplification of manufacturing and assembly procedures- one worker can perform all the tasks
- Reduced number of manufacturing/ assembly workers
- Effective utilization of workspace
- Cleaner and better organized factory
- Better possibility to increase production volumes

- More flexibility for boat designers
- Quick exchange of information between customer, dealer and manufacturer
- Less scrap
- Faults early detected

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