Lean approach applied to product development

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Abstract: The various competitive advantages of the application of the principles of the Toyota Production System (TPS), or simply Lean Principle, have created for the companies the need to adapt product design to reality. The responsibility for the scope of the Lean benefits is not only of the manufacturing but also of the products. To fully gain from the benefits of TPS, companies need to consider the Lean principles during the development of products, so that they can generate appropriate designs for the TPS. Accordingly, this article determines its application at the early stages of product development given its influence on the product's life cycle and on the entire decision-making process involved in these steps. Thus, this paper proposes a method in which the stages of work are set based on the Lean principles with the goal of creating designs with lower-level waste.

Keywords: Toyota production system, lean principle, product development, lean development.

1. Introduction

The constant growth in competition in the market where the companies are in makes them execute their operations and processes with quality, using as little time and resources as possible. As a way to achieve those goals, it is common to find companies that apply the principles of the Toyota production system (TPS), also called lean manufacturing, or simply lean, in their manufacturing environments, since the Toyota approach is notable for eliminating wastes, thus increasing their competition ability.

Although effective, considering the TPS principles applied to the factory only is not enough, because the market demands that the products produced by the companies fulfill their needs and are available at the desired moment, factors that are not very influenced by the manufacturing. According to Morgan and Liker (2006a), the ability of the manufacturing having impact on the product sales is limited, it can influence productivity and quality, but it will hardly have impact on the definition of product value, costs and investments. As the authors state, the impact is done more efficiently when the Lean principles are applied to the product development.

Considering the Lean principles during product development, especially in the earlier stages, strongly contributes to a faster launching speed, besides making possible the conception of products focused on the client and lower levels of waste. As defined by Slack et al. (1997, p. 144), "the goal of designing products and services is satisfying the consumers, fulfilling their current or future needs and expectations." This definition meets the Lean approach, since the consumer, as determined in the TPS, must be the focus of the company, the actions of which should try to serve them as well as possible, since its process initiates and terminates on the client.

Literature presents a great deal of work listing the benefits of applying the TPS principles to product development, but its applications appears oriented to the development process *per se*, and not to the result, that is, conception. The many barriers found during the principles application, such as the lack of activity standards, as reported by Garza (2005) makes success hard to achieve, this problem being more evident when the focus is on the process.

This work, intending to reduce those difficulties, will highlight the product conception, allowing the achievement of the Lean benefits. This way, a method to consider the TPS principles during the initial stages of product development will be proposed, and as a result we expect the creation of a "lean" conception, that is, with lower levels of waste during its development.

2. The structure of the Toyota production system and its principles

To better understand the structure on which the proposed method is based, we present the focuses that ground the TPS, as presented on Figure 1. According to Liker (2005), they form the base that supports the system. According to Gary Convis (2001 apud LIKER 2005, p. 179) the focuses of the Lean approach are the source to reach better quality, costs and time levels, achieved through the engagement of people as to goals.

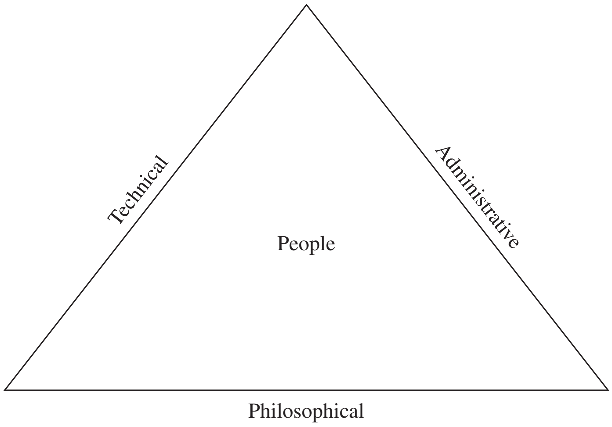

Figure 1. TPS according to Gary Convis, President of Kentucky's Toyota. (LIKER, 2005).

The philosophical focus refers to the basic thought that must support the system, the customer always first. The complete understanding of the market needs defines the concept of company value, and must be the director of all actions. The focus on administrative culture relates to the actions oriented to manage the organization and its projects. It helps with the execution of actions oriented to the customer, generates continuous learning and provides the system support culture, facilitating the dissemination of the philosophy to all employees. The technical focus relates to the application of actions and tools in the process, allowing improvements, making it easy to identify and eliminate losses. As we can see on Figure 1, in the center are people, who may be considered the heart of the system, since from them comes the quality and the commitment to the work done, so they must be valued and encouraged to achieve the quality levels desired.

Applying the aspects that form the TPS structure is fundamental so we can achieve a Lean character in the companies' processes, since it was grounded on "lean" principles, including, according to Morgan and Liker (2006), the focus on the customer, continuous improvement, quality thorough reducing wastes and the strong integration among the processes. In sum, one might say that "the thought is called lean because it is a way to do more and more with less and less… and, at the same time being closer to offer the customers exactly what they want" (WOMACK; JONES, 1996, p. 3). This way, one might define as a Lean principle the reduction of wastes focused on the customer figure. For such, this article will use the TPS focuses applied to the initial stages of product development so the conception generated will fulfill their principles.

3. Method description

To carry out the method, work stages were established, which must be fitted to the development process, so the conception is generated adequately to the TPS principles. To determine the stages, the focuses that ground the Lean approach were considered, aiming at bringing to product development a "lean" connotation. The proposed stages are:

- workload study;
- customer requirements setting and prioritizing;
- lean requirements setting;
- study of the interface between the possible solution principles proposed; and
- conception selection.

3.1. Workload studies

Evaluating the workload during product development may be considered a way to incorporate the technical focus of the TPS to product development, since it contributes to level out the work, helping with loss identification. Dimensioning the workload for the complete fulfillment of the design's schedule is fundamental to adequate the initial stages of product development to the TPS principles. According to Morgan and Liker (2006), using too much of the resources negatively influences development lead time, because when approximately 80% of the resource capacity is used it increases exponentially. According to Adler (1996 apud MORGAN; LIKER 2006), when around 80% of the resource capacity is used, any variability in the process causes delays, increase in lead time and quality problems.

Thus, the planning to use resources should be done during product development, especially in the initial stages, when there is a great demand for work and information. The allocation of resources in projects should foresee the real workload necessary to make the deadlines. The resource capacity must be used in a way to allow some "room" so that possible problems during the development can be solved without forming "bottlenecks", making it easier to meet the demand. To study the workload, we propose filling the table on Figure 2.

A refinement of the capacity study can be carried out, as shown on Figure 3. The highlighted cells indicate overload. Figure 3 shows an example of stage descriptions of an informational project. The same can be done to other project stages.

In case there are overloads and it is not possible to resize time or workload among the current members, carrying out this stage might indicate the need to an increase in the number of participants in the team. The availability of time dedicated to the project by each participant can also be reevaluated together with workload resizing, since some of them might have too much or too little time to meet the set deadlines.

3.2. Customer requirements setting and priorities

The inclusion of the philosophical focus in product development can be done through this activity, since on this

Number of participants on the team	5				
Project time (days)	100				
Total hours using 80% of capacity	640				
Identification	Ana	André	José	Carlos	Paulo
Time dedicated to the project (hours/week)	8	6	6	5	4
Available time of each participant (80% of capacity)	6.4	4.8	4.8	4.0	3.2

Figure 2. Dimensioning the team's workload.

stage the different customers' desires are analyzed, working as an orientation to the whole development.

The focus on the end customer is related to the definition of value to the organization. The concept of value, attached to the product, must be closely related to the end customers' perspective, since they determine it. According to Slack (1999), in the customers' vision the value of a product or service can be seen as a function of their ability to meet their yearnings, of the relative importance of the need fulfilled, of product or service availability and their acquisition costs. To the company, value is defined as any activity that does not meet its customers' needs, that is, that does not attach value to the commercialized product or service. According to Womack and Jones (1996), the company's value must be focused on the end customers.

The focus on the customer, when seen from the product development point of view, is crucial, especially in the earlier stages, because it orients its actions. Creating or enlarging the product variety from a mistaken definition of value generates great losses in the organization. As Womack and Jones (1996) report, the simple acceleration in the development process, not focusing on the customer, would be a big waste, since it would only accelerate the delivery of bad designs to the market. The correct value definition must be the starting point to create new designs, aiming at delivering to the market products that meet its needs with as little losses as possible.

The success of new products is strongly influenced by its productive process. According to Cecconello (2002), introducing new products to the manufacturing environment influences its performance. Manufacturing, when effective, gives the companies advantages, since according to Melo and Sacomano (2005, p.1) it can contribute to the operations performance, through the following actions: "the first one is understanding what is value to the customer and fit those values, the second is achieving the performance levels that make it prominent to the customer's eyes." One realizes that knowing the internal customer, that is, the productive process, allows a more refined critical vision of employees and leaders, and makes easier to continuously improve and promote a greater speed in problem solving, due to the reduction in the uncertainty levels. According to Bateman and Wild (2003), uncertainties on the manufacturability of the design during its development result in missed business opportunities, such as:

- profit reduction due to failures in choosing the best design, caused by uncertainties in the estimated costs;
- delays in production, customer unsatisfaction and extra cost, caused by poor evaluation of the processes' capacity as to demand;
- low yield and inferior quality of the product, due to wastes and quality problems;
- increase in inventory costs and problems in cash flow, caused by not considering the increase of inventories in the product's development stages; and
- flaws in the demand prediction systems, caused by not considering the manufacturing responsibility for meeting the demand.

Thus, we can verify the importance of keeping a relationship between manufacturing and the early stages of development, making product manufacturing easier through waste detection and elimination.

To carry out this stage, which begins with the result of researching the end customer's needs in each stage of the life cycle, the design team must attend to the needs obtained directly from the customers, rewriting them as requirements. Once the treatment is done, the different requirements must be valued, checking the importance of each one. For such, we propose a correlation matrix between needs, where we intend to measure the degree of importance of the different requirements compared with each other, that is, determining what adds value in the customer's vision. This task must be done with the customer's participation, so he/she can determine the requirements' degree of importance. Figure 4 presents an example of a correlation matrix focused on end customers, that is, the product user. The correlation between the requirements must be done in a comparative manner, for instance, when evaluating the importance of "Requirement 1" one must analyze if it is more, equally or less important than the other requirements. The degree of importance will be defined by the sum of requirements' points, giving priority to the one that presents the larger number of points.

Once the requirements are valued, the design team will have available the customers' vision as to requirements, which,

Informational Project	Day	Time (hours)	Ana		André		José		Carlos		Paulo	
			Dedicated hours	**Hours/ day**	**Dedicated hours**	**Hours/ day**	**Dedicated hours**	**Hours/ day**	**Dedicated hours**	**Hours/ day**	**Dedicated hours**	**Hours/ day**
Team selection	1	6	-	-	-	-	-	-	-	-	-	-
Determine team workload	1	4	-	-	-	-	-	-	-	-	-	-
Review and update product scope	14	40	20	1.4	20	1.4	-	-	20	1.4	-	-
Detail product's life and define its customer	8	60	40	5.0	-	-	20	2.5	-	4.0	-	-
Check if the products fits in any pre-existing family	8	30	-	-	40	**5.0**	-	-	-	-	-	-
Hierarchy of the final customer's requirements based on the concept of value	18	100	100	5.6	50	2.8	50	2.8	70	3.9	50	2.8
Hierarchy of the intermediary customer's requirements in: limitations, direct contributions, indirect and neutral contributions	20	150	100	5.0	100	**5.0**	50	2.5	50	2.5	-	-
Define product requirements (in hierarchy)	15	70	50	3.3	-	-	-	-	20	1.3	-	-
Define product specifications	15	100	50	3.3	-	-	50	3.3	50	3.3	40	2.7

Figure 3. Detail on workload.

if met, will add value to the final product. The result of this activity is the determination of the customers' requirement values, according to their degree of importance.

After this stage is done for the end customers, we must carry it out with intermediary and internal customers. Aspects should be risen that, if met, avoid wastes during the chain of production and product distribution. The result of this stage is surveying the needs of intermediary and internal customers, and the same matrix as presented in Figure 4 can be used.

3.3. Setting the Lean requirements

This stage incorporates the administrative focus of TPS, since it contributes to managing the organization and its projects, helping with the execution of customer oriented actions and strengthening the Lean culture.

The activity begins with the correlation between the different customers' requirements, trying to measure the degree of interference between those requirements and the end customer's. This correlation will determine which will be the requirements considered Lean, since it will evaluate them focusing on waste reduction and the ability to meet the customers' needs. Those which obtain the highest score will be met. The result of this activity will be used in selecting solution principles, contributing to setting the optimal conception. Figure 5 demonstrates an example of how the correlation between the different customers' requirements could be done, resulting in the Lean requirements.

The matrix was filled considering the interference among the requirements, writing the value "-3" in case the correlation between the requirements was negative, "3" if positive and leaving blank if neutral. The requirement score calculation was done by multiplying the correlations and the importance, for intermediary, internal and end customers. The design team should be cautious with scores that equal "0", since those might mean that the negative correlations annul the positive ones, or that the requirements' correlation is neutral. Thus, Figure 5, where we present the prioritized Lean requirements, cannot be used without a joint analysis with Figure 6, where we can check each correlation's details.

The capital letter presented before each requirement in Figure 6 refers to the origin of the need, where P means production and A assembly, and it can be adapted to the company's needs.

Using the matrixes in Figures 5 and 6 allows the design team to see which are the requirements that contribute to fulfilling the customers' needs, as well as their conflicts, helping with decision making.

3.4. Study of the interface between the possible proposed solution principles

This stage contributes to the application of the administrative focus of TPS, since it contributes to decision making focused on the long term, transferring this concept to the new designs, making them sustainable throughout their life cycle.

The TPS argues that decisions must be pushed to lower uncertainty levels, since the modification costs along the project increase with time. The application of this concept can be done through the set-based approach. According to Ward et. al (1995), the set-based works with the design uncertainties that are associated to sustainable competitive advantages. Ford and Sobek (2005) state that delays in design decision might add value to the products, in case the delay occurs in a way to allow selecting the optimal solution. The set-based approach contributes to the sustainability of decisions made about the design, since as the degree of uncertainty decreases, that is, as close to the launch as possible, it is possible for the companies to add a greater value to the designs, because some needs are more explicit. According to Ford and Sobek (2005), the set-based works with the construction of a set of viable alternatives to multiple perspectives those are gradually eliminated, aiming at selecting the optimal option. The authors state that the elimination of solution principles occurs as they present flaws that interfere with the design, such as: performance, costs, manufacturability and integration.

Many organizations present a convergence model called point-based, in which the design solution is decided initially, and improvements and modifications take place with various interactions among the areas affected along the development. The numerous iterations consume from the companies time and resources and do not necessarily lead to an optimal design (MORGAN; LIKER, 2006). Working the convergence towards the best solution, through the set-based approach allows the use of the TPS principles during product development. According to Morgan and Liker (2006a), the set-based approach eliminates wastes, since once the solution is chosen there is hardly any rework.

			Requirement								
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
			A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
Requirement	**1**	**A**		5	3	3	1	1	1	5	19
	2	**B**	1		1	1	1	1	3	3	11
	3	**C**	3	5		3	1	1	3	3	19
	4	**D**	3	5	3		1	1	3	1	13
	5	**E**	5	5	5	5		1	5	5	21
	6	**F**	5	5	5	5	5		3	5	25
	7	**G**	5	3	3	3	1	3		5	18
	8	**H**	1	3	3	5	1	1	1		14

Figure 4. End customers' requirements correlation matrix. Correlation: 5 - more important; 3 - equally important; and 1 - less important.

			Requirement								
		Importance	1	2	3	4	5	6	7	8	Score
	Importance		0.14	0.08	0.14	0.09	0.15	0.18	0.13	0.10	
Production	Reduce number of components	0.07	**-3**[a]	3		3		3	3	3	0.09
Production	Use standard components	0.06	0	3		3	3	3	3		0.11
Production	Use materials compatible with the production process	0.08	3			3		3		3	0.12
Production	Avoid complex geometries	0.08		3		**-3**[a]	3		3	3	0.09
Production	Avoid secundary processes	0.10			3	0	3				0.09
Production	Use modular architecture	0.09	3	3		3	3		3	3	0.19
Production	Use standard manufacturing processes	0.08		**-3**[a]							–0.02
Production	Use reliable supply chain	0.05					3			3	0.00
Production	Produce with existing cells	0.11	3	3		3		3			0.16
Production	Robust subsystems	0.05	3	3					**-3**[b]	3	0.03
Production	Project according to the expected prodution volume	0.05	3	3		3		3	3		0.10
Assembly	Simplify assembly	0.07	3	3	0	0	3		3		0.10
Assembly	Non-ambiguous assembly	0.05	3	0	3	0	3		3	3	0.10
Assembly	Minimize number of assembly axes	0.05	3	0	3	0	3	3	3	3	0.11

[a]Lean requirements having impact on important customer needs- Doing a PDCA; [b]Meeting the lean requirement, low need importance.

Figure 5. Matrix of correlation between customer requirements. Correlation: - 3 negative; 0 neutral; and 3 positive.

Aiming at selecting the optimal conception, we suggest that during the product development an analysis is done on the interface between the possible solutions to different parts of a same product. The interfaces should be satisfactory to all involved and must contribute to the product's global performance, not of its parts. Figure 7 presents an example, using the PMS32 (Problem Solving Matrix) software, of how the interfaces can be confronted. It should be filled comparing the interfaces, determining how they relate. "0" is attributed to incompatible subsystems.

In the columns go the principles of solution, equal initials represent solution alternatives to a same subsystem. The next step is generating in the PSM32 software the visualization of subsystem incompatibility concentration, as seen on Figure 8.

The design team visualizing the subsystems incompatibilities in a concentrated manner may opt for eliminating some of the solutions or reformulating them so there is integration between the interfaces. Interface compatibility determines the possible combinations that might form the product's architecture. The solutions considered acceptable are compatible with all the parts of the product.

3.5. Conception selection

This stage consists in selecting the solutions that will form conception; only the ones compatible with one another must be evaluated, as proposed on section 3.4. Each solution principle should be evaluated, its ability to meet the customers' needs, to generate lower waste levels and to use better supply chains.

	Lean requirements	Score
P	Use modular architecture	0.19
P	Produce with existing cells	0.16
P	Use materials compatible with the production process	0.12
P	Use standard components	0.11
A	Minimize number of assembly axes	0.11
A	Non-ambiguous assembly	0.10
A	Simplify assembly	0.10
P	Project according to the expected prodution volume	0.10
P	Reduce number of components	0.09
P	Avoid complex geometries	0.09
P	Avoid secundary processes	0.09
P	Robust subsystems	0.03
P	Use reliable supply chain	0.00
P	Use standard manufacturing processes	–0.02

P = production; A = assembly

Figure 6. Prioritized lean requirements.

First of all, the subsystems must be evaluated facing the customers' needs, that is, the product's desired performance. Figure 9 presents a model of correlation between the solution principles and the customers' specifications. Each solution principle will be scored on its ability to meet the specifications, giving it "5" in case it strongly meets, "3" for a fair service, "1" for a deficient service and leaving the cell blank in case it does not apply.

The alternatives that present different solutions to the same function, or group of functions, will be grouped. Figure 8 presents them grouped and represented by the same letter.

Filling the matrix on Figure 9 allows the company to evaluate, among the alternatives to the same solution principal, those which better serve the end customer. When the alternative is selected, the ones generating lower levels of wastes should be selected. The evaluation in this stage is done through the Lean requirements. Figure 10 presents a model of how the company will be able to evaluate the performance of the alternatives under the Lean requirements. Filling this matrix is done the same way as in the one presented on Figure 9.

The result of Figure 10's correlation are the alternatives that better meet the Lean requirements, that is, the ones that generate the lower levels of waste.

When the matrix on Figure 10 is filled, the company can perform a study on the performance of its possible suppliers. Figure 11 presents an example of how this study can be done. To fill in this figure we start defining each supplier for the selected alternatives. The suppliers will be individually evaluated in matrixes, like the one presented on Figure 11; each criterion must be evaluated putting an "x" next to the corresponding performance level. The suppliers' classification will be done from the total of points accumulated by them.

As the suppliers are classified, each alternative will be evaluated according to its supply chain, given priority to the ones with the best suppliers. Figure 12 presents an example of how the company might correlate the subsystems and the supply chain.

The total score on each alternative can be used the following manner: points will be attributed to each supplier

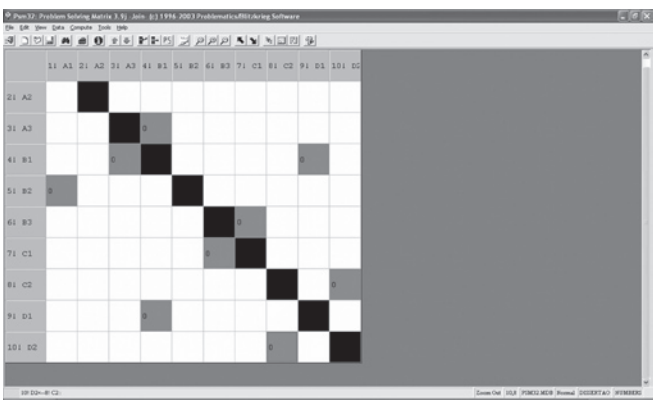

Figure 7. PSM interface correlation matrix.

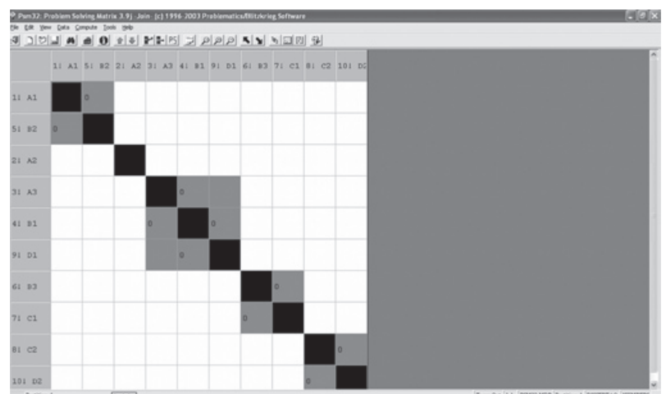

Figure 8. PSM matrix: visualization of incompatibility blocks.

		Goal specifications													Total
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
Score		**1.66**	**0.46**	**1.41**	**2.29**	**0.68**	**3.07**	**0.89**	**0.64**	**1.32**	**0.10**	**1.71**	**0.10**	**0.28**	
Subsystms	A1														
	A2														
	A3														
	B1														
	B2														
	B3														
	C1														
	C2														
	D1														
	D2														

Figure 9 . Subsystem selection according to their meeting of goal specifications. Correlation: 5 - strongly meets; 3 - fairly meets; 1 - poorly meets; and 0 - does not meet.

		Lean requirements														
		P	P	P	P	A	A	A	P	P	P	P	P	P	P	Total
		Use modular architecture	Produce with existing cells	Use materials compatible with the production process	Use standard components	Minimize number of assembly axes	Non-ambiguous assembly	Simplify assembly	Project according to the expected prodution volume	Reduce number of components	Avoid complex geometries	Avoid secundary processes	Robust subsystems	Use reliable supply chain	Use standard manufacturing processes	
Score		**0,19**	**0,16**	**0,12**	**0,11**	**0,11**	**0,10**	**0,10**	**0,10**	**0,09**	**0,09**	**0,09**	**0,03**	**0,00**	**-0,02**	
Subsystms	A1															
	A2															
	A3															
	B1															
	B2															
	B3															
	C1															
	C2															
	D1															
	D2															

P = production; and A = assembly

Figure 10. Subsystem selection according to the lean requirements. Correlation. 5 - strongly meets; 3 - fairly meets; 1 - poorly meets; and 0 - does not meet.

	Supplier de nitinol				
Criteria	**Poor**	**Fair**	**Good**	**Very good**	**Excellent**
Deadline meeting					
Partnership time					
Quality of products delivered					
Information exchange					
Reliable productive process					
Productive capacity					
Multiplied by:	0	↓			
Total	0	2	↓		
		0	4	↓	
			0	6	↓
				0	8
				Total	0
					0

Figure 11. Supply chain evaluation. Supplier < 12 - Poor; 12 ≤ Supplier < 18 - Fair; 18 ≤ Supplier ≤ 30 - Good; 30 < Supplier ≤ 36 - Very Good; and 36 < Supplier ≤ 48 - Excellent.

used by it, adding 4, 3, 2, 1 and 0 points to each supplier ranked as excellent, very good, good, fair and poor, respectively. The alternatives that present the highest scores among the alternatives to a same part of the product will be chosen; and along with the other selected ones they will build the optimal conception for the product.

4. Conclusion

The method presented here has as its main orientation waste reduction. For that, it uses as its action guide the customer's voice, that is, the definition of value coming from the market. Its application allows integration among the various areas of the company involved with the product, being all of its needs considered and analyzed.

The greatest advantage of the presented method is application flexibility, since it is not limited to companies that have a lean productive process, allowing them to enjoy several benefits, such as:

- greater interaction among the parts involved with the process, thus allowing the loss reduction through previously detecting problems;

		Suppliers													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Classification		G	VG	F	P	E	E	VG	G	F	P	P	F	VG	
Subsystms	A1														
	A2														
	A3														
	B1														
	B2														
	B3														
	C1														
	C2														
	D1														
	D2														

E = Exellent; VG = Very Good; G = Good; F = Fair; P= Poor

Figure 12. Conception selection according to supply chain.

- allows the anticipated visualization of conflicts between the areas involved;
- wider visibility of the customer figure, since it is present in different stages of the process, being the action director;
- better product quality, since it is conceived based on the expectations of the end customers;
- reduction in design costs, due to lower rework levels;
- reduction in development lead time, due to the correct planning of activities; and
- selection of the optimal conception.

As its main result, we expect the companies to reach better competitive levels, achieved through products that meet the consumers' needs, thus favoring their success and sustainability.

5. References

BATEMAN, J. T.; WILD, D. Design for manufacturing: use of a spreadsheet model of manufacturability to optimize product design and development. **Research in Engineering Design**, v. 14, n. 2, p. 107-117, mar. 2003.

CECCONELLO, I. **Adequação de um sistema de administração da produção à estratégia organizacional**. 2002, 140 f.. Dissertation (Masters in Production Engineering)- Post-Graduation Program in Production Engineering, Federal University of Santa Catarina, Florianopolis, 2002.

FORD, D. N.; SOBEK, D. K. Adapting Real Options to New Product Development by Modeling the Second Toyota Paradox. **IEEE Transactions On Engineering Management**, v. 52, n. 2, p. 175-184, May 2005.

GARZA, L. A. **Integrating Lean Principles in Automotive Product Development Breaking Down Barriers in Culture and Process**. 2005, 111 f. Dissertation (Master of Science in Engineering and Management) Massachusetts Institute of Technology, 2005.

LIKER, J. K. **O Modelo Toyota**. Porto Alegre: Bookman, 2005, 320 p.

MELO, J. G.; SACOMANO, J. B.; Manufatura enxuta – vantagem competitiva baseada na dimensão tempo. In: **SIMPÓSIO DE ENGENHARIA DE PRODUÇÃO**, 12., 2005, Bauru, SP, Relações de Trabalho no Contexto da Engenharia de Produção. Bauru, SP: SIMPEP, 2005.

MORGAN, J.; LIKER, J. K. **The Toyota Product Development System- Integrating People, Process and Technology**. New York: Productivity Press, 2006, 400 p.

SLACK, N. et. al. **Administração da produção**. 2 ed. São Paulo: Atlas, 1997, 757 p.

SLACK, R. A. The lean Value principle in military aerospace product development. **The Lean Aerospace Initiative**, Cambridge, MA, July 1999.

WARD, A. et al. The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster. **Long Range Planning**, v. 28, n. 4, p. 43-61, August. 1995. Elsevier

WOMACK, JAMES P.; JONES, DANIEL T. **A mentalidade enxuta nas empresas**. 7 ed. São Paulo, SP: Campus, 1996, 408 p.