INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

TRAPPED ON THE WASTE NET: A METHOD FOR IDENTIFYING AND PRIORITIZING THE CAUSES OF A CORPORATION'S LOW PRODUCT DEVELOPMENT PERFORMANCE

M. V. P. Pessôa and W. Seering

Keywords: waste reduction, product development process improvement, lean product development

1. Introduction

The Product Development System (PDS) is an organizational system that manages both the product portfolio and each individual product development [Cheng 2003]. The PDS is on the interface between the enterprise and the market; it has the duty of identifying (or even anticipating) the market's needs, and proposing how to fulfill these needs [Rozenfeld et al. 2006]. A high performance PDS, therefore, is capable of consistently articulating market opportunities that match the enterprise's competencies [Cheng 2003], and executing the Product Development Process (PDP), guaranteeing that progress is made and value is added by creating useful and timely results [Murman et al. 2002].
The PDP itself is a creative, innovative, interdisciplinary, dynamic, highly coupled, massively parallel, iterative, communication based, uncertain, and risky process of intensive planning and activity [De Meyer et al. 2002], [Negele et al. 2009]. Consequently, a wide spectrum of variables can affect its success.
On "lean terms", low performance is the consequence of waste. In the Toyota Production System (TPS), "waste refers to all elements of production that only increase cost without adding value" [Ohno 1998, p. 54] or "any human activity that absorbs resources but creates no value" [Womack and Jones 2003, p. 16]. In fact, the TPS is "a method to thoroughly eliminate waste and enhance productivity" [Ohno 1998, p. 54].
Dvir, Lipovetsky, and Shenhar [2003] concluded that, despite the fact that a wide spectrum of variables can affect the success of a project, the project success factors are indeed contingent upon the specific type of project and that the list of project success factors is far from universal. Consequently, finding the most relevant waste's root causes is a complex task.
This work aims to propose and validate a method that (1) represents the causal relationship between common sources of problems in product development projects and wastes on the PDS perspective; and (2) determines and prioritizes the possible root causes to wastes on a particular project. The proposed method interconnects three elements: the wastes themselves, the categories of root causes to wastes, and the challenging PD characteristics.
This paper is divided into six sections. Section 2 discusses definitions and particularities of the product development system and process that were the basis to the method's challenging PD characteristics, and presents the references on problems in development projects that helped the definition of the method's root causes categories and subcategories. Section 3 shows the method's waste set. On section 4, the proposed PD Cause-Waste Net is presented. Section 5 describes the method and its validation. Finally, on section 6, some conclusions and suggestions to future work are discussed.

2. Low performance on product development systems

New product development is a particular type of production whose main raw material is information [Bauch 2004]. Through the PDP the information is turned into specifications, or some sort of "product recipe", to be produced [Reinertsen 2005]. Ulrich and Eppinger [2004, p. 2] define Product Development (Process) as "the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product". Rozenfeld et al. [2006] added the PDP scope to the after-launch follow-up and necessary evolutions, and the planned discontinuity. During its execution, the PDP takes account of the market needs, the technological opportunities and restrictions, and the performing organization competitive strategy [Rozenfeld et al. 2006].

A low performance PDS can be the consequence of issues that negatively impact on the performance indicators of product quality, product cost, development time, development cost, and production capability. In the literature explicit and implicit listings are found on these issues ("problems in projects"). Explicit listings enumerate the problems themselves [Cooper 2001], [Dvir et al. 2003], [Bauch 2004], [Kato 2005], while implicit listings suggest sets of best practices to solve implied problems [ISO/IEC 1995], [CMMI 2002], [PMI 2013].

Pessôa [2008] merged these explicit and implicit listings into 156 subcategories that were further grouped into 16 categories and 4 sources. The farthest to the development core the source is, the less power to deal with its related issues the company has. Figure 1 shows the four sources according to their "proximity" to the development itself, its inner categories of problems and the number of related subcategories (in parenthesis). For a detailed description of all the sources, categories and subcategories see Pessôa [2008].

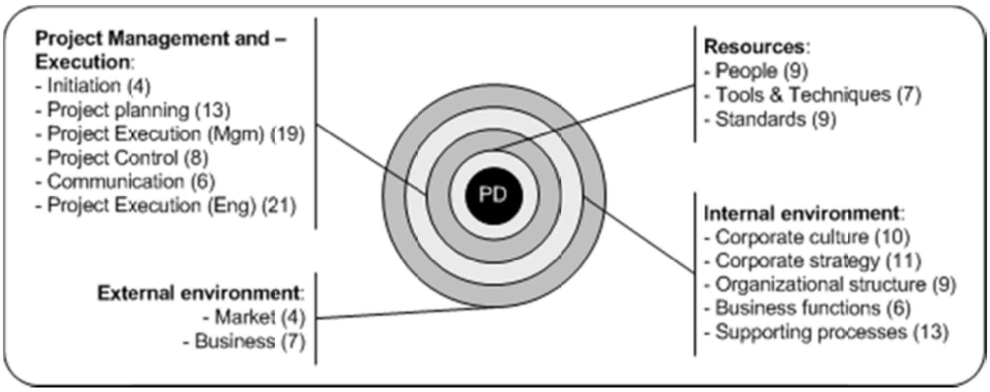

Figure 1. Sources of problems and their categories

3. Wasting on the PDS point-of-view

Ohno [1998, p. 57] defines three types of work: (1) value-added work that is the processing that adds value in the sense the customer perceives it; (2) non-value added work that are things that have to be done under present work conditions to support the value-add work; and (3) pure waste. According to the lean thinking/philosophy, the waste reduction and elimination is paramount to high performance product development systems.

The authors decided to use a waste set that is a merging of previous work on the Lean Production System and on the Lean Product Development System [Ohno 1998], [Womack and Jones 2003], [Liker 2004], [Bauch 2004], [McManus 2004], [Gershenfeld and Rebentisch 2004], [Kato 2005], [Morgan and Liker 2006] and [Ward 2007]. Instead of trying to translate the waste definitions from the production system to the product development system, this work assumes that the waste causes the deterioration of the following PDS elements [Pessôa 2008]: input, process, output, environment, feedback, control, and resources (Figure 2). The choice and organization of the waste drivers do not greatly differ from what is presented in the literature. Whenever possible, the original waste nomenclature was maintained, in order to avoid misinterpretations and misunderstandings. The most relevant contribution on the set is the inclusion of "Happenings", as a waste type rooted in the external environment.

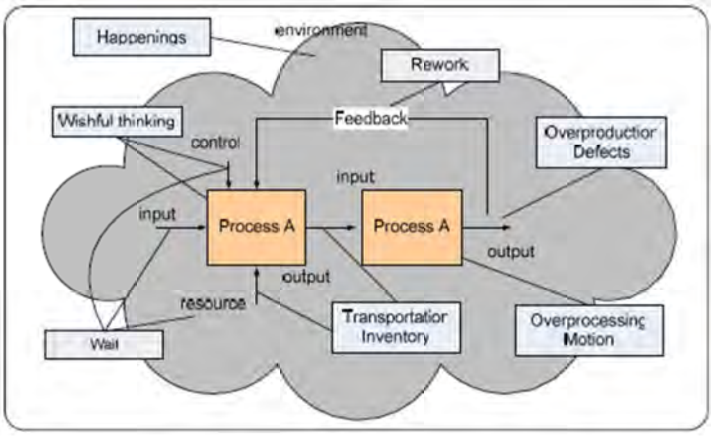

Figure 2. Wastes and the PDS elements (source: [Pessôa 2008, p. 15])

A set of 10 waste drivers was considered in order to better link the drivers to the PDS elements. Each of the 10 waste types have subtypes (Figure 3) that better define their scope (see Pessôa [2008] for a detailed description of all the presented waste types and subtypes). Indeed, the root causes of unscheduled waste (caused by variations from the planned) differ from the root causes of scheduled waste (normally a result of bad planning or the consequence of resource allocation restrictions).

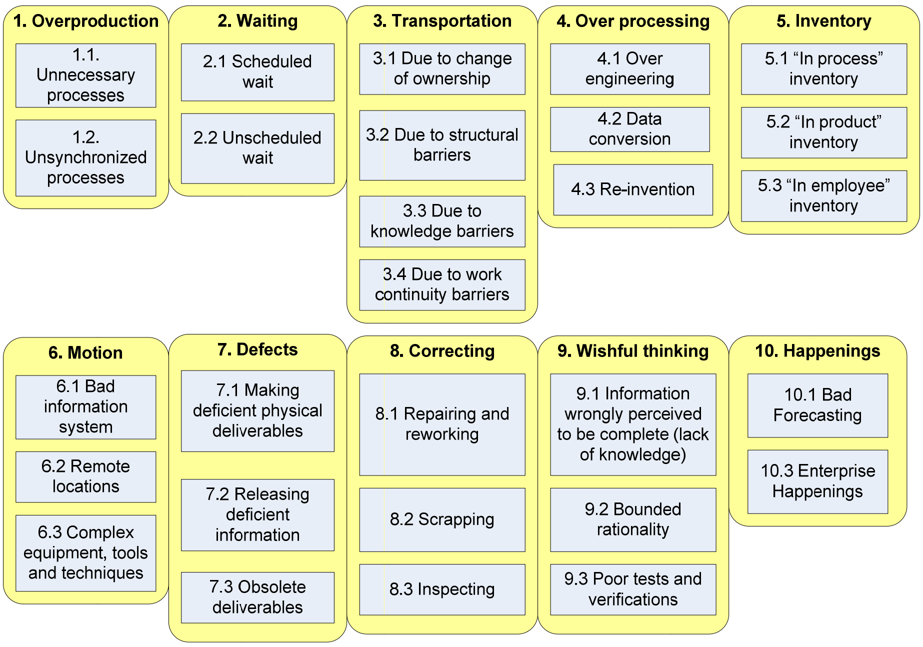

Figure 3. Waste types and subtypes (source: [Pessôa 2008, p. 16])

4. The "Product Development Cause-Waste Net"

The method presented in this work uses a systematic representation of the two-way relationship between wastes and causes. This representation, called "PD Cause-Waste Net", consists of three elements: (1) 10 waste types broken down into 28 subtypes; (2) 4 sources of problems in PD projects divided into 16 categories and 156 subcategories; and (3) 14 challenging PD characteristics. The cause subcategories trigger the waste subtypes through an intricate net: the causes can influence on several wastes and at different degrees, and the wastes themselves might be the result of multiple causes. The method (Figure 4) represents this net, where the cause-waste relationship is calculated by multiplying the matrices representing the linking between the cause subcategories and the challenging PD characteristics, and between the PD characteristics and the waste subtypes. Consequently, the more similar the relationships between (1) a particular waste subtype and the challenging PD characteristics and (2) a particular cause's subcategory and the PD challenging characteristics, the higher the expected impact among causes and wastes.

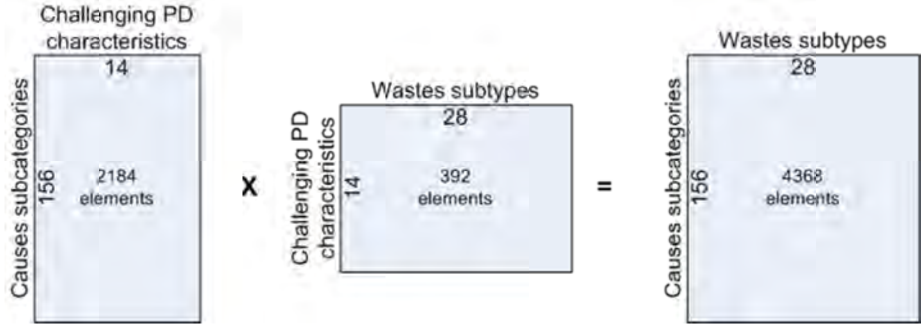

Figure 4. Relationship between the challenging PD characteristics, the causes and the wastes

The authors emphasize that proposing a final and universal mapping among the waste subtypes, characteristics PD characteristics and causes subcategories is beyond the scope of this paper. Consequently, this paper presents a generic method that can be adopted for PDS improvement, where individuals or organizations should do this mapping based on local conditions and constraints. The following subsection describes and justifies the choice of the challenging PD characteritics.

4.1 Challenging PD characteristics

A set of 14 "challenging PD characteristics" was chosen by referring to the literature, [Schrader et al. 1993], [Negele et al. 1999], [Loureiro 1999], [Cooper 2001], [De Meyer et al. 2002], [Cheng 2003], [Ulrich and Eppinger 2004], [Rozenfeld et al. 2006], and by adjusting with the set of waste driver types and cause categories. These characteristics constitute an intermediate layer between the wastes and their causes, with the objective of creating a reduced and coherent set to link wastes and causes. The authors do not attempt to propose a final and complete characterization of PD, but list some of the important and challenging peculiarities inherent to the product development system. The chosen characteristics were:

1. Duration fluctuation: The time to perform an activity will not likely be the same either if it is done by different persons or if the same person does the same activity on different opportunities. Product development processes will always embody statistical fluctuation during their execution. Higher deviations from the average execution time are expected when dealing with new processes, innovative products, and unmastered technologies.
2. Iteration: Iteration is the procedure by which repetition of a sequence of operations yields results successively closer to a desired result. Iteration can be planned (iterative process) and unplanned (rework). Too complex design/ poor interface design may lead to more iteration. The higher the number of unplanned iteration cycles the worse.
3. Interruption: Critical design issues, trivial questions, unplanned communication, multitasking, etc. always arise during the development. Though natural, the higher the interruption level on the development projects the worse.
4. Teamwork (communication/coordination): The bigger, more distributed, and more multidisciplinary the development team the more intensive is the needed communication and coordination to keep the work aligned.
5. Teamwork (cooperation): As the complexity of the product increases, the number of different expertises needed to design it also increases. A cooperative environment with mutual help and knowledge sharing is paramount to the development success.
6. Uncertainty (resource availability/performance): Uncertainty varies according to the adequacy, availability, and capacity of the resources (including people) during the development execution.
7. Uncertainty (what/how to do): The customer needs or project goals might not be clear, and the information that flows during the development often carries a level of uncertainty.

8. Uncertainty (outputs accuracy/performance): The accuracy and the performance of the development outcomes are not completely predictable, particularly when using new processes, developing a highly innovative product, or using an unmastered technology.
9. Structure complexity: The performing organization's structure is becoming more and more complex to be able to deal with increasing product and process complexity, and to adapt to global markets and distributed development.
10. Processes/tools complexity: The increasing number of processes and tools and the challenge to keep them integrated at some level creates issues to the effective and unambiguous communication.
11. Product complexity: Besides the products themselves, which are more and more complexes, the product development scope includes not only the final product itself, but also its life-cycle processes and the performing organizations of these processes.
12. Changes: Nothing ever happens exactly the way it was planned (changing requirements, resources unavailability, etc.). High change rates compromise the development progress.
13. Ambiguity: The existence of multiple and conflicting interpretations on known and required information is common on PD, turning the information inconsistent.
14. People based: The development is performed by people that themselves have their own culture, values, personality, idiosyncrasies, etc. Rather than considering the person's adequacy and performance on the development, this characteristic states that individuals may present unpredictable behaviours ("boxes of surprises").

In the method, the use of the challenging PD characteristics as an intermediate layer had the objective of simplifying the definition of the relationships, by:

- Reducing the total number of links to be initially filled - If mapped directly there would be a total of 4368 link points to be filled, using the intermediate layer this number decreases to 2576 (2184 + 392).
- Reducing the subjectivity of the linking procedure - A particular cause subcategory can affect different wastes with different intensity, the application of a multi-levelled criteria (i.e. always cause, can cause, never cause), though, has been proven difficult to use [Bauch 2004].

By mapping through the challenging PD characteristics the crisp relationships (1 – related, and 0 - not related) on the [cause subcategories] versus [challenging PD characteristics], and the [challenging PD characteristics] versus [waste subtypes] matrices, the resulting [cause subcategories] versus [waste subtypes] matrix has values ranging from 1 (since all causes and wastes had to be connected to at least 1 challenging PD characteristic) to 14 (in the hypothetical case that a particular waste is related to all challenging PD characteristics and is caused by a subcategory that is itself related to all challenging PD characteristics too).

4.2 The "Product Development Cause-Waste Method"

The two-way relationship between causes and wastes (Figure 4) can be tracked through the matricial product according to equation 1, where:
[A] is the matrix containing the [cause subcategories] versus [challenging PD characteristics];
[B] is the matrix containing the [challenging PD characteristics] versus [waste subtypes]; and
[C] is the resulting matrix containing how each [cause subcategory] affects the each [waste subtype] triggering.

$$[A]*[B]=[C] \tag{1}$$

The linking between the causes and the characteristics was made by answering whether each cause subcategory exploits any of the challenging PD characteristics. Whenever the answer was "yes" the cell was "checked", thus receiving the value 1. Figure 5, Matrix [A], shows an example where the communication subcategory "not clear knowledge of which/where are the team members" is capable to exploit the "duration fluctuation" PD characteristic, since it causes more time consumption during the activities while people try to figure out who or where are the team members, while it has no influence in increasing the number of development iterations.

The linking between the challenging PD characteristics and the waste subtypes was made by answering whether each characteristic contributes to the occurrence of a particular waste. Whenever the answer was “yes” the cell was “checked”, thus receiving the value 1. Figure 5, Matrix [B], shows an example where the waste subtype “unnecessary processes” is influenced by the number of iterations in the project, but is not affected by the “duration fluctuation”.
To exemplify, Figure 5, Matrix [C], presents a subset of the resulting matrix, containing the relationships between the communication subcategories and the overproduction subtypes. On the presented example, the “not clear knowledge of which/where are the team members” is capable to exploit “duration fluctuation,” “teamwork (communication/ coordination),” “changes,” and “ambiguity.” Consequently, the presence of this subcategory contributes to the occurrence of the “unnecessary processes,” by influencing 3 out of 7 challenging PD characteristics that are, themselves, related to this waste subtype.
As shown, the dependencies were determined by the authors themselves. Further revisions of subsets of the relationships were made by some MIT graduate students and professors. The validation of the model and assumed relations was made by practitioners on two different companies (discussed on Section 6). This mapping considered that all causes subcategories are present and with the same level of influence on the project. In reality, though, it is very unlikely that in a particular enterprise all causes subcategories will be either present or with the same level of influence, which justifies the need of defining a method to model each company.

[A]

Root Cause Subcategories	Challenging PD Characteristics	Duration fluctuation 1	Iteration 2	Interruption 3	Teamwork (communication/coordination) 4	Teamwork (cooperation) 5	Uncertainty (resource availability/performance 6	Uncertainty (information on what/how to do) 7	Uncertainty (outputs accuracy/performance) 8	Structure complexity 9	Processes/tools complexity 10	Product complexity 11	Changes 12	Ambiguity 13	People based 14
Not clear knowledge of which/where are the team members	1	1			1								1	1	
Ineffective team meetings	2				1		1						1	1	
Ambiguity or multiple understandings	3	1			1		1	1	1				1	1	1
Uncontrolled broadcasting of information	4	1		1										1	
Lack or lack of strict enforcement of reading/replying rules	5	1			1										

[B]

Challenging PD Characteristics	Waste Subtypes	1.1. Unnecessary processes 1	1.2. Unsynchronized processes 2
Duration fluctuation	1		1
Iteration	2	1	
Interruption	3		1
Teamwork (communication/coordination)	4	1	1
Teamwork (cooperation)	5		
Uncertainty (resource availability/performance)	6		1
Uncertainty (information on what/how to do)	7	1	1
Uncertainty (outputs accuracy/performance)	8		
Structure complexity	9	1	
Processes/tools complexity	10		1
Product complexity	11		
Changes	12	1	1
Ambiguity	13	1	
People based	14	1	

[A]*[B]=[C]

[C]

Root Cause Subcategories	Waste Subtypes	1.1. Unnecessary processes 1	1.2. Unsynchronized processes 2
Not clear knowledge of which/where are the team	1	3	3
Ineffective team meetings	2	3	3
Ambiguity or multiple understandings	3	5	5
Uncontrolled broadcasting of information	4	1	2
Lack or lack of strict enforcement of reading/reply	5	1	2
Leadership: executives’ communication is thin an	6	3	3

Figure 5. Linking example

5. The method for applying the PD Cause-Waste Net to a particular corporation

In order to allow the pratical use of the PD Cause-Waste Net a method was defined, including a discount factors to represent the peculiarities of each company. Equation 2 includes these factors, represented as Matrix [T], to the Equation 1.

$$([T]*[A])*[B]=[C] \tag{2}$$

The method was tailored for the reality of two different companies, in order to verify whether it: (1) is capable to discern the particularities of different companies; (2) is capable to picture the enterprise reality; and (3) is practical to use. The two companies were: an American enterprise that operates on the home appliances market (company A), and a Brazilian company that develops products under contract to the aerospace industry (company B).

To capture the particularities of each company the method uses a discount factor that rates the occurrence likelihood of each of the root causes subcategories. Practitioners from the companies answered a questionnaire on occurrence frequency of each root cause subcategory in their enterprise: High, Medium, Low, or NO, corresponding to factors 1, 0.7, 0.3, and 0, respectively. The factor was multiplied to the linking already defined between the cause's subcategories and the challenging PD characteristics. Figure 6 shows how the answers from company A (represented on matrix T) changed the calculated results previously presented on Figure 5.

[T]

Communication: not clear knowledge of which are the	105	Low	0.3
Communication: ineffective team meetings	106	High	1
Communication: ambiguity or multiple understandings	107	High	1
Communication: uncontrolled broadcasting of informat	108	High	1
Communication: lack or lack of strict enforcement of re	109	Medium	0.7
Communication: leadership: executives' communicatio	110	Low	0.3

[A]

Root Cause Subcategories	Challenging PD Characteristics	1 Duration fluctuation	2 Iteration	3 Interruption	4 Teamwork (communication/coordination)	5 Teamwork (cooperation)	6 Uncertainty (resource availability/performance	7 Uncertainty (information on what/how to do)	8 Uncertainty (outputs accuracy/performance)	9 Structure complexity	10 Processes/tools complexity	11 Product complexity	12 Changes	13 Ambiguity	14 People based
Not clear knowledge of which/where are the team members	1	1			1								1	1	
Ineffective team meetings	2				1		1						1	1	
Ambiguity or multiple understandings	3	1			1		1	1	1				1	1	1
Uncontrolled broadcasting of information	4	1		1										1	
Lack or lack of strict enforcement of reading/replying rules	5	1			1										

[B]

Challenging PD Characteristics	Waste Subtypes	1 1.1. Unnecessary processes	2 1.2. Unsynchronized processes
Duration fluctuation	1		1
Iteration	2	1	
Interruption	3		1
Teamwork (communication/coordination)	4	1	1
Teamwork (cooperation)	5		
Uncertainty (resource availability/performance)	6		1
Uncertainty (information on what/how to do)	7	1	1
Uncertainty (outputs accuracy/performance)	8		
Structure complexity	9	1	
Processes/tools complexity	10		1
Product complexity	11		
Changes	12	1	1
Ambiguity	13	1	
People based	14	1	

([T]*[A])*[B]=[C]

[C]

Root Cause Subcategories	Waste Subtypes	1 1.1. Unnecessary processes	2 1.2. Unsynchronized processes
Not clear knowledge of which/where are the team	1	0.9	0.9
Ineffective team meetings	2	3.0	3.0
Ambiguity or multiple understandings	3	5.0	5.0
Uncontrolled broadcasting of information	4	1.0	2.0
Lack or lack of strict enforcement of reading/reply	5	0.7	1.4
Leadership: executives' communication is thin and	6	0.9	0.9

Figure 6. Application of the discount factor

The questionnaire answering took approximately two and a half hours to each respondent to complete, during which they received assistance from one of the authors, showing that the model is practical to use.

The particularized matrices were then used to calculate the prioritized subcategories to each company, as presented on Table 1. Table 1, column "overall impact", also shows the most relevant root causes subcategories, according to the theoretical situation presented in Section 4.2. These causes were the ones with higher total sum of their influence to the waste subtypes. Through the matrices is also theoretically possible to estimate the waste causes.

By presenting different results, the model is shown to be capable of discerning differences between enterprises. The results were further presented to practitioners on both enterprises and all agreed that they quite well picture their reality, both on the more and on the less impacting subcategories, thus validating the model's results.

Table 1. More relevant cause subcategories

Cause Subcategory	Overral Impact	Impact on Company A	Impact on Company B
Communication: ambiguity or multiple understandings	1	1	3
Standard Process: unclear/absent task ownership	2	2	11
Execution: lack of shared vision	3	7	4
Integration: Inconsistence between plans or plans' parts	4	32	23
Tool: complex equipment, tool or technique	5	14	109
Tool: lack of integrated solution that meet the requirements of all users	6	37	9
Structure: unclear or mismatching policies, roles and rules	7	3	17
Execution: priorities not clearly defined	8	21	1
Strategy: missing or rather unclear objectives/targets	9	34	25
Tech Solution: lack of concurrent engineering	10	85	6
Execution: doing without knowing or understanding	32	4	18
Execution: poorchange management	14	5	2
Execution: poor WIP version management	15	6	19
Initiation: project objectives are narrowly defined and/or unclear	35	8	24
Execution: inadequateinformationdelivered	11	9	29
Execution: poorknowledgetransfer	12	10	30
Structure: scatteringstructure	23	33	5
Strategy: confidentialityof expertise	43	149	7
Strategy: technology development concurrent with development of product	13	13	8
Execution: multitasking	51	40	10

6. Discussion

The method presented in this work provides a systematic way to analyze the two-way cause-waste linking on the context of a product development system (PDS). The method uses a representation of this linking calles "PD Cause-Waste Net", consisting of three elements: (1) 10 waste types broken down into 28 subtypes; (2) 4 sources of problems in PD projects divided into 16 categories and 156 subcategories; and (3) 14 challenging PD characteristics. These elements are linked through the multiplication of a [cause subcategories] versus [challenging PD characteristics] matrix, and a [challenging PD characteristics] versus [waste subtypes] matrix. The resulting matrix shows how much a given subcategory can influence triggering each waste subtype.

Through the relationship between its elements the method provides three different contributions. The method can estimate the waste occurrence likelihood: given a (some) cause(s) the expected waste occurrence likelihood can be verified by the relative impact on the cause-waste matrix. Also through the cause-waste matrix, the probable causes of a particular waste (or group of wastes) can be estimated. Finally, the method can make an enterprise waste-cause assessment: by assessing the occurrence of the problem's causes in a particular company, it is possible to verify their impact on waste occurrence, and to prioritize the causes' elimination.

By studying an example of a possible mapping between the model's elements, useful insight was gained about the implications of waste causes on the PDS. However, if the conceptual structure presented in this paper is to achieve its full potential, more work must be done. Additional studies are required to more fully capture the relationship among the root causes, the challenging PD characteristics, and the wastes.

The type of analysis illustrated here may outline the study of other issues related to the coupling of product development waste subtypes and its root causes on particular business environments and development projects. A challenge for future research is to extend this model to explore the consequences of acting on these specific causes (i.e. applying the lean principles and practices) and the expected implications on the waste net.

This study uses an example with connections defined by the authors' discretion. Another future challenge is to capture an empirically grounded linking from lean thinking experts and from practitioners, and change agents, in order to both validate a general model, as well as assess its usability in PDS change interventions.

References

Bauch, C., "Lean Product Development: Making waste transparent", Thesis (Diploma) – Massachusetts Institute of Technology, Cambridge, 2004.

Cheng, L. C., "QFD em Desenvolvimento de Produto: Características Metodológicas e um Guia para Intervenção", Revista Produção Online, Florianópolis, Vol. 3, No. 2, 2003.

CMMI, "Staged Representation" (CMMI-SW, V1.1, Staged), CMMI for Software Engineering, Version 1.1, 2002, CMMI Product Team, Pittsburgh: Software Engineering Institute – SEI, (Technical Report CMU/SEI-2002-TR-029), 2002.

Cooper, R. G., "Winning at New Products: Accelerating the Process from Idea to Launch", 3.ed., Cambridge: Perseus Books Group, 2001.

De Meyer, A., Loch, C. H., Pich, M. T., "Managing project uncertainty: From variation to chaos", Sloan Management Rev., Vol. 43, No. 2, 2002, pp. 60–67.

Dvir, D., Lipovetsky, S., Shenhar, A. J., "What is really important for project success? ", International Journal of Management and decision Making, Vol. 4, No. 4, 2003, pp. 382–404.

Dvir, D., Raz, T., Shenhar, A. J., "An empirical analysis of the relationship between project planning and project success", "International Journal of Project Management", Vol. 21, 2003, pp. 89–95.

Gershenfeld, J., Rebentisch, E., "The Impact of Instability on Complex Social and Technical Systems", Proceedings from MIT Engineering Systems Division External Symposium, 2004.

ISO/IEC, "Information Technology – Software Life Cycle Processes", ISO/IEC 12207:1995/Amd 1:2002/Amd 2:2004.

Kato, J., "Development of a Process for Continuous Creation of Lean Value in Product Development Organizations", Thesis (Master), Massachusetts Institute of Technology, Cambridge, 2005.

Liker, J. K., "The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer", New York: McGraw-Hill, 2004.

Loureiro, G., "A systems engineering and concurrent engineering framework for the integrated development of complex products", Thesis (PHD) - Department of Manufacturing Engineering, Loughborough University, Loughborough, UK, 1999.

Mcmanus, H., "Product Development Value Stream Mapping (PDVSM) Manual", Beta draft, Cambridge: MIT Lean Aerospace Initiative, 2004.

Morgan, J. M., Liker, J. K., "The Toyota product development system", New York: Productivity Press, 2006.

Murman, E., Allen, T., Bozdogan, K., Cutcher-Gershenfeld, J., McManus, H., Nightingale, D., Rebentisch, E., Shields, T., Stahl, F., Walton, M., Warmkessel, J., Weiss, S., Widnall, S., "Lean Enterprise Value", New York, Polgrave, MIT's Lean Aerospace Initiative, 2002.

Negele, H., Fricke, E., Schrepfer, L., Härtlein, N., "Modelling of Integrated Product Development Processes", In: Annual Symposium of Incose, 9th., Proceedings…[S.l.]: [s.n.], 1999.

Ohno, T., "Toyota production system", New York: Productivity Press, 1998.

Pessôa, M. V. P., "Weaving the waste net: a model to the product development system low performance drivers and its causes", Lean Aerospace Initiative Report WP08-01, MIT, Cambridge, MA, 2008.

PMI, "A Guide to the Project Management Body of Knowledge", (PMBOK® Guide), 5.ed., Project Management Institute, Newton Square: Project Management Institute, 2013.
Reinertsen, D., "Let it flow. "Industrial Engineer"", ABI/INFORM Global, Vol. 37, No. 6, Jun 2005, pp. 40-45.
Rozenfeld, H., et al., "Gestão de Desenvolvimento de Produtos", São Paulo, Editora Saraiva, 2006.
Ulrich, K., Eppinger, S., "Product Design and Development", 3rd ed., New York: McGraw-Hill, 2004.
Ward, A., "Lean product and process development", Cambridge, The Lean enterprise Institute, 2007.
Womack, J. P., Jones, D. T., "Lean Thinking", New York, Free Press, 2003.

Marcus Pessoa, Ph.D., Head of Operational Division
CISCEA, Operational Division
Av General Justo, 160, 20021-130 Rio de Janeiro, Brazil
Telephone: +55-21-2123-6374
Telefax: +55-21-2532-7295
Email: mvpessoa@gmail.com
URL:http:// www.ciscea.gov.br