A C T A   U N I V E R S I T A T I S   L O D Z I E N S I S
FOLIA OECONOMICA 235, 2010

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MULTIVARIABLE ANALYS PROBABILITY PLOTS OF PRODUCTION SCHEDULE

Abstract. In this paper the author analyses probable plots of finished deadline terms for tasks from 4 cargo sister ships for 224 tasks per each of them, realized on one from division in polish shipyards. Indirectly using Six Sigma tools like: Gage R&R and Multivariable Analysis. Directly using indicators Cp (Pp) i Cpk (Ppk), evaluating in this way the efficiency of planed processes. He proposed a way of costs calculating loss possibilities resulting from delays in schedule realization, near foundation, that Cp (Pp) is percentage budget execution. He also compared those results with the ones he got using Taguchi's loss function.

Key words: Six Sigma, USL, LSL, Cp, Pp, Cpk, Ppk, schedule, production risk, operating risk, multivariable study, Gage R&R, multivariable analysis, efficiency, productivity.

I. TESTING OF PROBABILITY PLOT'S OF REALIZATION DATE'S

For many years there have been discussions about enterprise risk and even about managing it. However it has not been shown how to calculate it. We assume that we talk about production risk in enterprise but not about credit risk, market risk (currency, interest rate) and operating risk taken by financial institutions which regulate documents like:

1. Capital Requirements Directive (CRD) [7], [8]
2. Markets in Financial Instruments Directive (MiFID) [9], [10], [11], [12],
3. A new capital adequacy framework – Basel II [1], [2], [3], [4], [16]

Here we have to deal with dependence that enterprise production risk is very often in some part taken as a bank credit risk. Market risk touches exports firms in case of hesitation of currency courses, meanwhile interest rate risk is for enterprises working for example with high financial leverage, but those risks are far away from operating production management.

This study shows risk as a probability plots in realization of deadline terms production tasks using Six Sigma methodology. Conducted analysis as an aim has to describe processes efficiency and costs of loss possibilities resulted from schedule delay (contract delay) and also allowing for recommendations related with corrective and preventive actions. The author proposed exemplary control

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charts for project and process and appoint key parameters in Six Sigma methodology, like USL, LSL, Cp (Pp), Cpk (Ppk).

Efficiency control we are using mainly to {elaborated on base [6]}:

1. Formulate recommendation making possible accomplishment of necessary changes and process, project, product improvement;
2. Help in identifying possibilities of deliverable more better products and services in the same costs or cheaper;
3. Using obtained information for better operating managing;
4. Demonstrating the possibilities of costs fall without the fall of quality and quantity;
5. Increase and production improvement and services without expense increase;
6. Weakness identification in actual controls and processes for better usage of resources.

However one should have consciousness where are the real savings in the process of improvement, it is actually that for 100[%] delay in tasks realization - 80[%] reason is human factor and 20[%] technical factor. Within this 80[%] - 64[%] is as a result of bad management and rest 16[%] not corrective operator [14].

In quality conception it looks like Six Sigma distinguishes 3 ways efficiency calculating related with product quality [15]. Those gauges aren't proper to production risk valuation, take in this paper as a risk of delay in schedule tasks realization, they are giving only quantity of mistakes in produced elements and on this base it is possible to take some conclusions according to measured assortment.

Risk management in some range was dealt with by W. Shewart (~1924) and W.E. Deming. First of this man proposed variability processes division on controlled and non controlled [15]. In further stage he proposed controlled processes division on stable, coherent, random and predictable. Non controlled he divided on: non stable, non coherent, non predictable, however their reasons are possible to qualification. Result of this work was control charts realization used in SPC.

Mr. W.E. Deming proposed simultaneously variability processes division on division from general and specific reasons [15]. In general reasons division variability is described using parameters like: internal for system, controlled by board and possible to correct only by board. In second case changeability may have local nature, not being normal system property and might be corrected locally. Both of this man aspire to understand processes variability, (with one in latest period described as a risk) and to fully control it.

Actually the best reflection of enterprise production risk in my opinion showed Mrs. J. Bizon-Górecka in paper [5], where she disengage reputation, technology, organization, management and finance variability (risk). Technology changeability depend on: quality, access to advanced technology, technical devices and technical progress. Organization variability depends on:

operator experience variability and process harmonization. Management variability depends on: logistic variability, competitive position, agreement with law, personnel managerial, macroeconomic. Financial variability depends on: correct price offer, costs estimation, cash flow, credit ability, given guarantees and investment variability.

Surely each from this division we may consider in different category, however at first of all mainly important are frames described process variability in enterprise and what is connected with it enterprise production risk. I want show it using control chart, because for good every process is generating some risk if it is important for organization it might by and should be observed here I propose to do it using control chart. However, to show my control charts proposition I need to consider two important tools to this analysis: Multi Variable Study and Gage R&R.

First of this tools giving us next steps to stable process analysis (Cp, Cpk) as also periodically stable (Pp, Ppk), those processes we may also decompose, multivariable analyzing as also we may come to them using virtual tools (Design of Experiments - DOE). When we are using multivariable analysis we are monitoring actions and tasks, as a result of this observation we are planning, implementing and guiding changes, with ones stabling our operations in time. After each change we study their influence on analyzed process and next we describe operating tolerance (standard, norm) to which we bring back accepting the process {specification USL, LSL (TABLE 1), capacity Cp (Pp), Cpk (Ppk) (Drawing.1, Drawing.2)}.

Second from this tools permit for process variability observation, involving real process variability and measurement variability. Changeability measurement is described through the test sample variability – as a result of service staff it does mean repeatability with it's variability of means measured by different operator using the same measuring devices during the same sample measurement. We also have here changeability as a result of extension, with one we divided on [15]:

1) exactitude – it is difference between observed mean and real;

2) precision (replication) – repeatability – the same operator using the same measuring device makes measurement the same sample;

3) stability – bring back to difference between mean from last two measurement settings the same measuring device in the same measure sample, measure in different times. Population stability showing do we have drift, shift, trends, cycles etc.;

4) linearity – it is the difference in precision and measuring of the device range, or difference in value precision and expected measurement device range, it is aspect when we use the same measuring devices by supplier and consumer;

5) separable – here we have the aspect when we try to divide all processes, we are checking – they are separable or not, maybe we have here bimodal process.

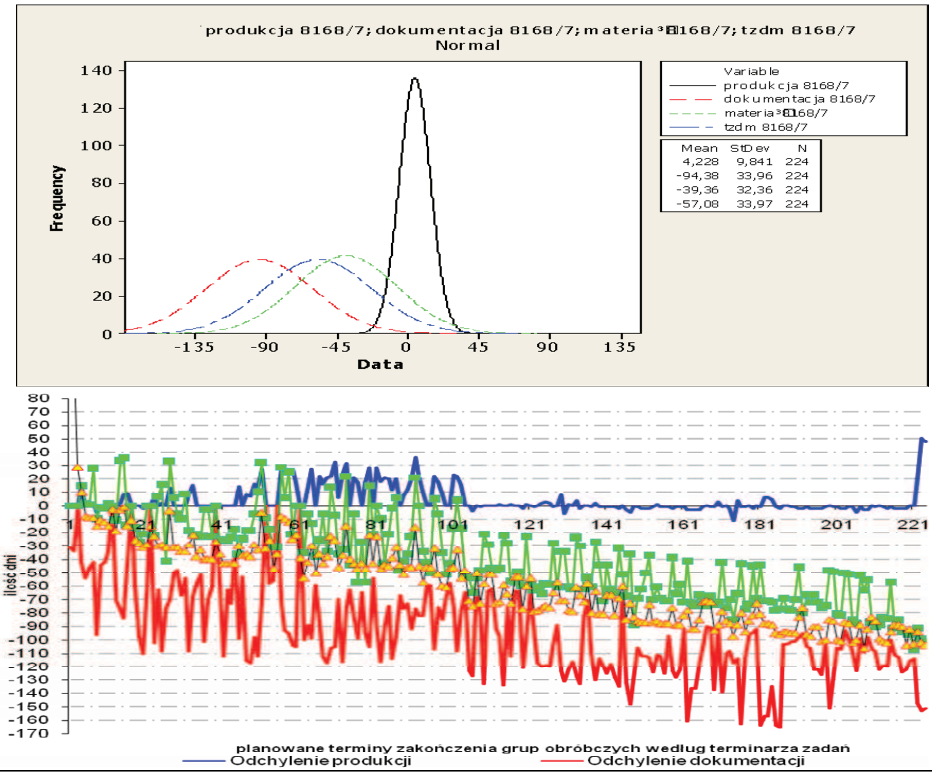
Based on probability plots establish, than process specification limits (USL, LSL) should be in following time interval with reference to planned deadline, being a deadline:

Table 1. Position low (LSL) and upper (USL) limit specification

	Proces limit specification	LSL	USL
1	Production	–7days	+7 days
2	Material delivery	–75 days	–28 days
3	Technical documentation delivery	–105 days	–75 days

Specification ranges are volume with one we are trying to find, exactly it is shown on latest part of this paper on drawing 3.

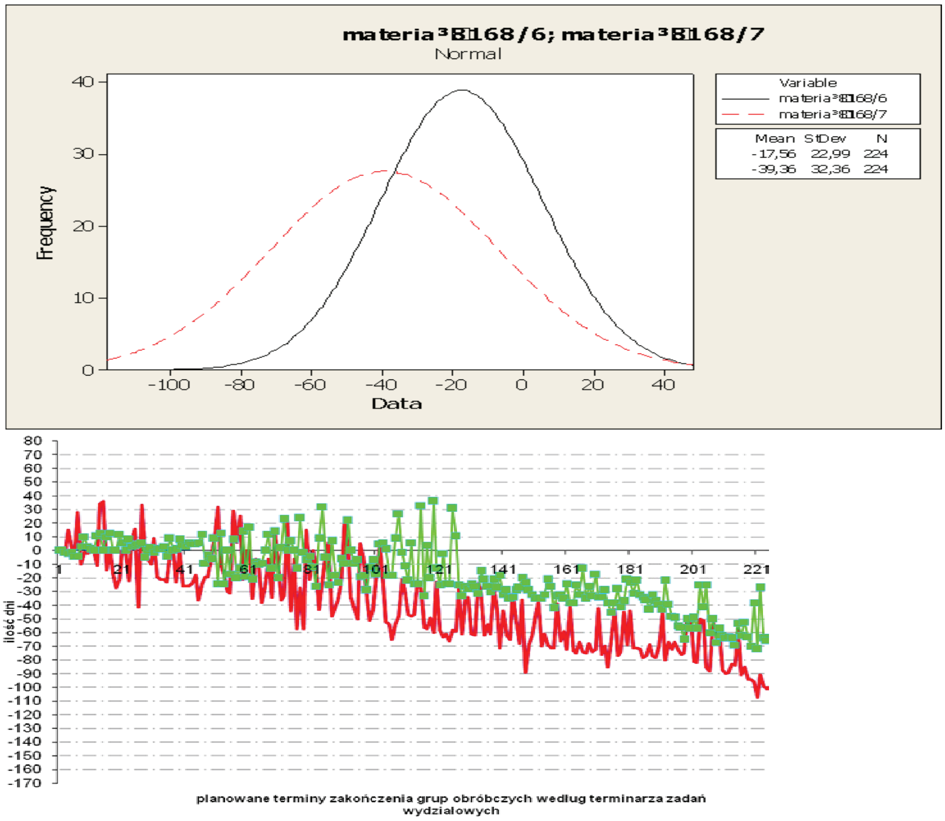
Drawing.1. Example control chart for project {elaborated on base [13]}.



PROJECT - Long Term (LT)								
	Mean	ST.Dev.	Z.Bench	Z.Shift	Yeld	DPMO	Pp	Ppk
8168/7 –production	4	9	1,11	1,5	86,67	133314	0,60	0,38
8168/7 - material	–39	32	–0,05	1,5	47,81	521930	0,23	0,1
8168/7 – technical drawings	–94	33	–0,42	1,5	33,83	661664	0,15	0,1

Top part of this drawing shows comparison of probability plots of finished production dates tasks for processes: production, material delivery, tzdm – planning office main schedule for material and documentation. Middle part of this drawing shows production process (line close to X axis); material delivery (second line from X axis), tzdm – third line from X axis, documentation – most external line from X axis. Down part shows obtained results summary table.

Drawing.2. Example control chart for process



PROCES ZAOPATRZENIA MATERIAŁOWEGO – Long Term (LT)								
	Mean	ST.Dev.	Z.Bench	Z.Shift	Yeld	DPMO	Pp	Ppk
8168/7	–39	32	–0,05	1,5	47,81	521930	0,23	0,1
8168/6	–17	23	–0,56	1,5	28,82	711823	0,33	–0,18

Top part of this drawing shows the example of comparison for statistical plots of finished deadline material delivery tasks for processes from sister projects 8168/6 (line closer X axis) and 8168/7 (most external line from X axis). Down part shows obtained results summary table.

Obtained in this way results (Drawing.1,Drawing.2) let me interpret studied processes in way like below [15]:

Mean – for first project X/7 tasks were done in 39 days before deadline in average, time interval is between established parameters TABLE 1, but for second X/6 it is 17 days in average that is incorrect planning task;

ST.Dev. – standard deviation showing deviation 23-32 days from mean, that's telling us that in some events we come across established parameters from TABLE 1;

Z.Bench (Sigma) – process benchmark is between -0,05 to -0,56 , high indicator shows better results, (it should be about 1,0; parameter -0,05 is critical weak);

Z.Shift – showing hidden production possibilities because Z.Shift ≥1;

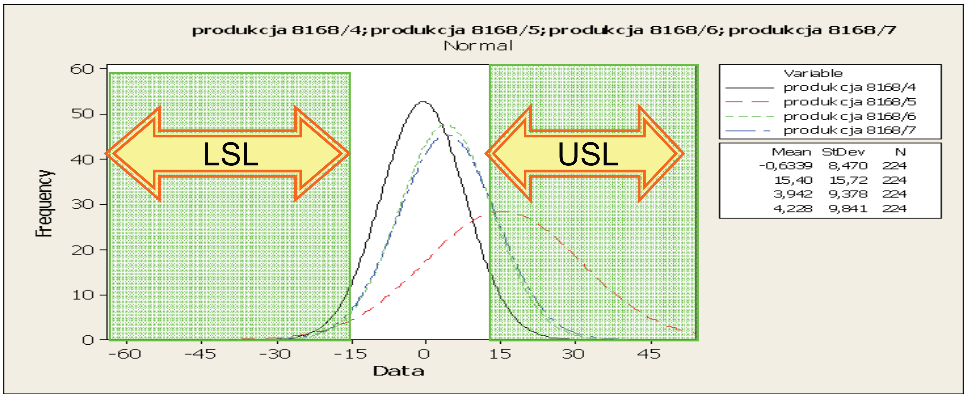
Yield – telling us that random chosen value has in Long Term (LT) {above one year} from 28,82[%] to 47,81 [%] chance to be in interval +/– 3 standard deviation from mean;

DPMO – expected value of defects per 1[mln], in 6sigma it is 3,4 defects per million.

Pp (Cp) – process efficiency let us focus on aim researched probability plot, results close 1,0 are good, excellent is above 1,0. It's enumerated as a difference between high limit specification (USL) and low limit specification (LSL) divided by 6 standard deviation.

Ppk (Cpk) – process capacity showing drift, trends (stability) of probability plot, witch if is closer 1,0 that better. Is enumerated as a difference between high limit specification USL (or low limit specification LSL) and mean divided by 6 standard deviation – it should be taken smallest from this two results.

Drawing 3. Graphical interpretation of limit specification LSL and USL - influence moving this on achieved capacity indicators Cp (Pp). Way of mark Cp (Pp) shown when this indicator was interpreted



If we take Pp(Cp) indicator as a real percentage parameter of process efficiency than we may compare it with enterprise budget where we are planning the income referred to as a process and projects. If we are establishing some budget on project or process, and we know that expected efficiency is Pp(Cp)=0,60 (efficiency = 60[%]) than we must involve a budget reserve on 40[%] budget losses or prepare financing for this process / project from another process / project. Results show us that we should expect 40[%] schedule replacement and only in 60 [%] hold in to the plan. It means that realized process / project has realization delay witch we may take as a loss possibilities because during planning consideration the resources witch enterprise have would be used in 100 [%], but established result weren't accomplished. We should describe this situation as a production risk witch may replace rest from realized process and projects in company and also outside company on cooperation.

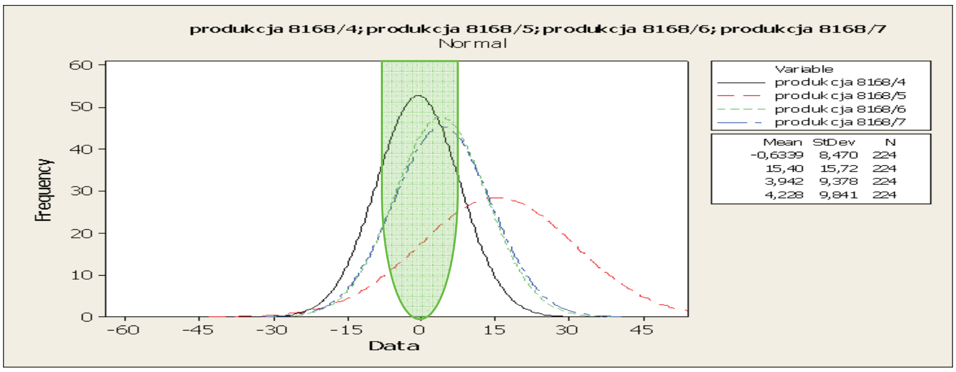
Expected loss we may enumerate using Taguchi's loss function:
formula (1) elaborate on base [17]

$$Loss = Division\ working\ day\ in\ [PLN]\ \ x \frac{(norm - how\ many\ days\ we\ standard\ established\ for\ deviation) - (real\ deviation}{(loss\ size\ with\ minimum\ deviation - 1\ day)^2}$$

where:

Division working day in [PLN] – total division cost sum per month divided by the quantity of days in month; *norm* – zero days deviation from plan; *how many days we standard establishing for deviation* - LSL (USL) from TABLE 1; *real deviation – results taken from* MiniTab.14 program, down part drawings 1,2; *loss size with minimum deviation* – we establishing norm as a zero, this value also is zero

Drawing 4. Graphical interpretation of loss possibilities using Taguchi loss function



When we take real data, results taken using Cp (Pp) as a percentage indicator budget consumption and Taguchi's loss function are similar TABLE 2.

Table 2. Result comparision

	Loss mhr]	Loss [zł]
Tagouchi's loss function	32.048	–865.305
Based on Pp (Cp)	31.266	–844.185

Dividing the process that has bad indicators on under processes (for operations) we may find defect results and remove it. Described analysis shows that different processes we may analyze finding a common point for example production tasks and than connect them with realization dates. Problems may appear when we have many different products and small quantity of tasks. The analyzes shows also that if we keep discipline during schedule realization according to budget plan we may do even few projects more during year.

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WIELOCZYNNIKOWA ANALIZA ROZKŁADÓW STATYSTYCZNYCH HARMONOGRAMÓW PRODUKCYJNYCH

Autor w pracy przeanalizował rozkłady statystyczne terminów wykonania z 4 siostrzanych statków, po 224 zadania na każdym z nich, realizowanych na jednym z wydziałów polskich stoczni, pośrednio za pomocą takich narzędzi metodologii Six Sigma jak: Gage R&R oraz analizy wieloczynnikowej. Bezpośrednio za pomocą wskaźników Cp (Pp) i Cpk (Ppk), oceniając w ten sposób wydajność zaplanowanych procesów. Zaproponował sposób wyliczenia kosztów utraconych możliwości wynikających z opóźnień w realizacji harmonogramu, przy założeniu, że Cp (Pp) jest procentowym wykonaniem budżetu, jak również porównał te wyniki z wynikami uzyskanymi przy zastosowaniu funkcji strat Taguchi'ego.