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NEMAWASHI: Attaining Value Stream alignment within Complex Organizational Networks

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Abstract

In the process of value creation, organizations perform an intense intra-organizational dialog through which internal VS alignment is achieved towards certain strategic objectives. Within the context of complex organizational networks, were goal conflicts are preprogrammed through incentive structures, VS alignment as legitimation of action towards strategic goals has special interest. On the one hand it facilitates the access to necessary resources for goal achievement and on the other it increases the sustainability and supports commonly agreed upon decisions leading to success. This paper provides a winnerless process (WLP) differential equations model for quantifying intra-organizational value stream (VS) alignment dynamics that can help design sustainable lean management solutions. This paper presents ongoing research results that show how the model was implemented in one industrial facility.

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Keywords: Nemawashi; Winnerless Process; Value Stream alignment in Complex Networks; HOSHIN KANRI TREE; (CPD)nA.

Nomenclature

根回し	**Nemawashi**: the process of consensus building.
HKT	Hoshin Kanri Tree. Lean management method.
KPI	Key Performance Indicators.
PO	Process Owner.
VS	Value Stream Flow.
WLP	Winnerless Process

1. Introduction.

The most important aspect of strategic planning is, according to [1], the strategy process: “a dialog through which knowledge is shared and consensus is achieved and commitment towards action and results is built”. As shown in [2], consensus in organizations as legitimation of action towards certain strategic goals have attracted increasing levels of attention for legitimation facilitates the access to necessary resources to achieve such goals. These consensus can and should occur in different organizational settings, although in this paper the authors focus on those consensus related to the management of VS.

According to [3] organizations are complex systems that, from an information exchange perspective, can be considered as networks under the “organizational network” paradigm proposed in [4]. Typically the proper VS management comprehends the coordination of organizational clusters within such networks: different departments such as sales, engineering, production or logistics can be considered such clusters of highly interconnected hubs that are compelled to deliver coordinated solutions to ensure maximum VS performance. In this dynamics either they are all successful together or they will be unsuccessful individually.

The process of consensus building or **Nemawashi** can be described therefore as one in which all agents acting, at different levels; upon VS will reach a desired state after a

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finite time throughout a winnerless process (WLP) where no agent wins in the sense described in [5]. We hypothesize that the achievement of VS consensus depends dynamically on the performance of all related PO and, without loss of generality, that these interaction are linear within a discrete period of time.

The effective VS goal achievement sought by different organizational clusters may be however many times conflicting thus increasing the uncertainty of the task. Galbraith [6] assertively conjectured that the principal managerial task is to reduce uncertainty by processing information: "A basic proposition is that the greater the uncertainty of the task, the greater the amount of information that has to be processed between decision makers during the execution of the task". Individual behavior of rational people trying to achieve a local optimum may lead to organizational disasters as shown in [7] referencing to [8]. From an organizational network´s perspective, it is therefore crucial to understand the organizational dynamics towards a consensus on the quest towards VS goals.

In order to achieve this, the paper is structured in five phases: Firstly, a background on complex organizational networks. Secondly, a model that describes the **Nemawashi** process and conditions for VS alignment is provided. Thridly, a **Nemawashi** management roadmap for implementation as well as several management implications are presented. Fourthly, one case study is presented so as to show the application of the model and make it replicable. Finally, we discuss the conclusions and limitations of the model and present possible further research.

2. Background.

Organizational complexity measures the level of interdependence between organizational units as shown in [9]. Neuroscientists as Friston introduces the concept of effective connectivity as the influence one neural system exerts over another [10].

In a series of papers along these lines [11] have introduced the concept of **organizational structural connectivity** as a way to understand structural organizational networks formed by:

- nodes, organizational agents or PO, and
- edges or KPIs (Key Performance Indicators) related to PDCA (Plan-Do-Check-Act) understood as ***(CPD)nA*** (Check-Plan-Do-Check-Plan-Do-…-Act).

The concept of **organizational effective connectivity** is now introduced as a way to understand organizational networks in which

- nodes are structural network clusters around hubs of high cluster coefficient, and
- which edges dynamically describe the underlying causal influences between them measured through certain VS related time-dependent KPIs.

Villalba-Diez et al. have shown in previous papers that when implementing HKT as a VS oriented lean-management method, organizational clusters form along VSs [12].

Following the hypothesis formulated in the introduction, this VS can be described by n KPIs x_i $i=1...n$ that represent the VS performance.

For obvious computation reasons, in order make the KPIs comparable, these x_i need to be normalized and bounded.

Normalization occurs when

$$x_i^*=(x_i-x_{imin})/(x_{imax}-x_{imin}) \quad (1)$$

being x_{imax}-x_{imin} the maximum and minimum value of $x_i(t)$ and therefore $0 \leqq x_i^* \leqq 1$.

Boundaries are set if $x_i^{**}=x_i^*\cdot(100/\sum_i x_i^*)$ (2)

The dynamic variation of this normalized performance x_i owned by one of these clusters can be described by the differential equation system described in (2)

$$d\, x_i/dt=f_i(x_1^{**},x_2^{**},...,x_n^{**},t)\ ;\ i=1,...,n \quad (3)$$

This set of equations describes a trajectory, the **Nemawashi** consensus curve, in an euclidean n-dimensional space given. The authors consider VS alignment is attained if in this n-dimensional state euclidean space the trajectory described by the **Nemawashi** curve presents asymptotic stability as shown in [13].

As indicated by Freedman [14], this set of differential equations can describe several types of interactions that can be modeled by deterministic mathematical models in population ecology such as the Kolmogorov model. The **Nemawashi** WLP is a consensus seeking process with linear interactions between the POs. Therefore it can be potentially modeled by the particular Kolmogorov case formulated by the generalized Lotka-Volterra equations shown in [15].

This paper presents two main contributions:

- A system of differential equations to describe the **Nemawashi** process is proposed as well as the necessary conditions for VS asymptotic stability are described.
- A **Nemawashi** management roadmap for implementation as well as several management implications are presented.

3. Nemawashi process and conditions for VS alignment.

In the process of value creation, organizational clusters consume resources that are limited and ought to be distributed among all. All structural clusters seek to maximize the value they generate out of the consumed resources. Simultaneously, poled by the aligning force of the strategy, all VS agents are compelled to strive for solutions that best serve whole system´s performance. Both centrifugal, cluster interest, and centripetal forces, strategic interest, are brought in equilibrium by the incentive structure given in the organization. This incentive structure is operationalized by the KPI.

A model that describes the consensus problem within this KPI structure consists on n structural clusters, whose performance can be measured through certain KPIs. The present work considers a generalized Lotka-Volterra set of differential equations to describe the WLP model given by (4):

$$dx_i\,/\mathrm{dt}=x_i^{**}\cdot(r_i-\sum_j a_{ij}\cdot x_j^{**})\ ;\ i,j=1,...,n \quad (4)$$

where $r_i \geq 0$ represent the growth rate of the i^{th} VS related KPI,

and a_{ij} represent a constant interaction between the i^{th} and j^{th} KPI. The matrix $\boldsymbol{A}=(a_{ij})$ is called the interaction matrix.

Therefore the conditions of WLP are winnerless

$$0 < x_i^{**} < 1 \ \forall t \text{ for } i=1,\dots,n \qquad (5)$$

The state euclidean space is the nonnegative orthant $\Omega^n_+=\{x^{**}=(x_1^{**},\dots,x_n^{**}),\ 0<x_i^{**}<1 \text{ for } i=1,\dots,n\}$

For visualization purposes, in the rest of the paper, the authors will consider the VS is described by three KPIs being n=3. The system described in (2) for three variables can be described as follows:

$$dx_i/dt=x_i^{**}\cdot(r_i-\textstyle\sum_j a_{ij}\cdot x_j^{**})\ ;\ i,j=1,2,3 \qquad (6)$$

The conditions for asymptotic stability of every possible equilibrium are [13] given if (7), (8) and (9) are true:

$$\left.\begin{aligned} m_{11} &= a_{22} * a_{33} - a_{23} * a_{32} \\ m_{22} &= a_{11} * a_{33} - a_{13} * a_{31} \\ m_{33} &= a_{11} * a_{22} - a_{12} * a_{21} \end{aligned}\right\} \qquad (7)$$

$$\det(A) > 0 \qquad (8)$$

$$a_{13}\cdot a_{21}\cdot a_{32} + a_{23}\cdot a_{31}\cdot a_{32} - 2\cdot(a_{11}\cdot a_{22}\cdot a_{33}) < 2\cdot\left[\begin{aligned}\sqrt{a_{11}\cdot a_{22}\cdot m_{11}\cdot m_{22}} + \sqrt{a_{33}\cdot a_{22}\cdot m_{33}\cdot m_{22}} \\ +\sqrt{a_{11}\cdot a_{33}\cdot m_{11}\cdot m_{33}}\end{aligned}\right] \qquad (9)$$

In other words, (4) and (5) describe the **Nemawashi** consensus process and the inequalities (7), (8) and (9) describe the conditions for VS alignment.

The inequality (7) has a VS related interpretation. In the first inequality describing $m_{11,}$ the term $a_{22}a_{33}$ is a measure of competition and represent the competing effect on the growth of KPI x_2^{**} due to KPI x_3^{**}. The term $a_{23}a_{32}$ is a measure of inhibition and represent the damping effect between KPI x_2^{**} and KPI x_3^{**}. If the measure of competition, $a_{22}\cdot a_{33}$, is less than the measure of inhibition, $a_{23}\cdot a_{32}$, then an asymptotically stable coexistence may exist. The other inequalities in (7) have a similar VS related interpretation.

Inequalities (8) and (9) determine a lower and upper bound respectively for the difference between the measure of competition and the measure of inhibition for all three KPIs simultaneously.

4. Nemawashi Management Roadmap to VS alignment

*4.1. **Nemawashi** Management Roadmap*

The **Nemawashi** management roadmap proposes a five step computational process, based on genetic optimization algorithm.

- Firstly, a VS where VS alignment is strategically needed is mapped following any process mapping method. The authors recommend cross-functional process map or swimlane method proposed in [16].
- Secondly, three relevant KPIs at the highest level of the VS are measured throughout a period of time, to be then normalized and bounded following expressions (1) and (2).
- Thirdly, the coefficients $\mathbf{A}=(a_{ij})$ of the interaction matrix and r_i are inferred. As there are 8 parameters for each tern of KPIs there is a cost function defined $J(p1,..,p8,T)$ as the euclidean distance between the real position and the iterated solution for intervals $i=1,\dots,T$. A genetic optimization algorithm is applied to this cost function J in order to infer the optimal $\mathbf{A}^*=(a_{ij}^*)$ and r_i^* as described in [17].
- Fourthly, through (5) the WLP nature of the dynamical system is tested. If the parameters allow for a WLP dynamics, then a **Nemawashi** process can be found.
- Finally, in the case that **Nemawashi** process can be found with this set of KPIs, the necessary conditions for VS alignment (7), (8) and (9) are tested with these inferred $\mathbf{A}^*=(a_{ij}^*)$ parameters. The asymptotic point of VS alignment is represented in a ternary diagram.

At this point several management implications can be presented.

5. Case Studies.

In this paper we present a case study from one of the authors professional activities that aim to illustrate the implementation of the proposed **Nemawashi** Roadmap to VS alignment in the case of the Robert Bosch Automotive Steering GmbH.

5.1. Research Setting

In the Spiral Manufacturing VS (fig. 1) under consideration there are 35 team production members involved. The Spiral Manufacturing is a part of a more extensive two-geared electrical steering manufacturing in the Schwäbisch-Gmünd factory in which it is assembled. The first management level is responsible for the three KPIs, shown by Table 1, that describe this VS.

Table 1. Relation between KPIs Case Study 1

KPI	KPI Description	KPI Metric
1	Average Change Over Time	hours
2	Overall Equipment Efficiency (OEE)	%
3	Throughput	parts/week

5.2. Nemawashi Roadmap

- Firstly, the VS was mapped. As proposed by Womack, this was performed with all relevant POs following a standard Gemba Walk [18]. Fig. 1 qualitatively displays the result of such mapping. For confidentiality reasons such VS cannot be shown in more detail.

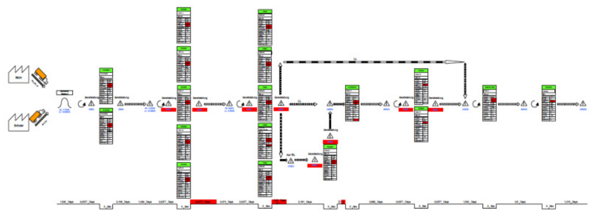

Fig. 1. Spiral Manufacturing VS. Robert Bosch Automotive Steering GmbH

- Secondly, the three mentioned relevant VS KPIs were measured on a weekly basis. The study intends to show if this given set of KPIs is suitable for a **Nemawashi** WLP given the gathered data. These KPIs are to be normalized and bounded following expressions (1) and (2) to the KPIs as shown in Fig. 2.

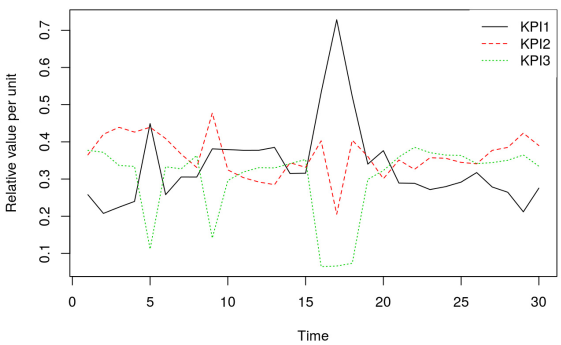

Fig. 2. Normalized and Bounded KPIs. Spiral Manufacturing VS.

- Thirdly, a genetic algorithm was implemented to infer the coefficients of the WLP differential equation system introduced in (4). In our particular case the selected chromosome has 12 real numbers between 0 and 1 (3 r_i and 9 a_{ij}), and we have used real value crossover and mutation with probabilities of 60% and 7% respectively. The population was built over 8000 individuals and it ran over 1000 generations. After that, the best configuration found propose the following coefficients:

$$A = \begin{bmatrix} 0.97 & 0.28 & 0.32 \\ 0.48 & 0.54 & 0.46 \\ 0.46 & 0.54 & 0.80 \end{bmatrix}$$

  As a result, conditions (7), (8) and (9) are fulfilled.

- Fourthly, through (5) the WLP nature of the dynamical system is tested. We conclude that the parameters allow for a WLP dynamics and a **Nemawashi** process can be found.
- Finally, because the conditions for **Nemawashi** are given and the process presents WLP dynamics, we are able to represent the expected asymptotic point of VS alignment in a ternary diagram as shown in Fig 3.

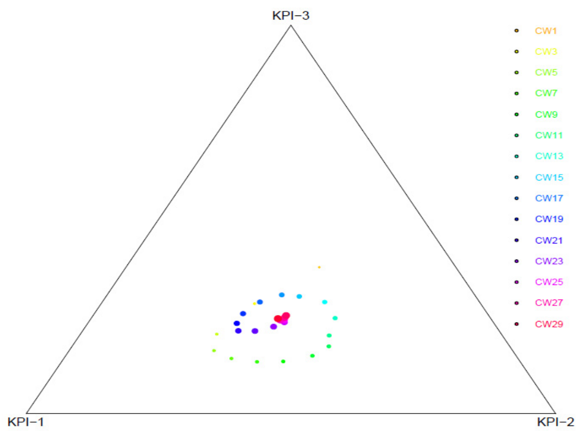

Fig 3. Ternary Plot Production VS.

5.3. Interpretation and Case Study Closure

We can conclude that given this VS, the set of KPIs provided can attain a state of WLP. Therefore the **Nemawashi** Process is possible.

The dynamics show that, under these VS conditions, the system can attain asymptotic stability through a **Nemawashi** process and therefore alignment is possible. The point of equilibrium is given in the ternary diagram when the KPIs have a relation shown by Table 2.

Table 2. Relation between KPIs Case Study 1

KPI	Relative KPI relationship
1	28%
2	29%
3	33%

When this point of equilibrium has ben reached, the VS agents have achieved alignment. This state of alignment provides a quantifiable direction worth guiding the continuous improvement.

6. Conclusions, Management Implications, Limitations and further steps.

In this ongoing research paper, the authors have proposed a plausible mathematical population dynamics WLP model to explain consensus seeking dynamics towards organizational alignment.

The authors enunciate several conclusions through following propositions as well as its related benefits which may help VS managers better manage the process:

- ***Proposition 1***. *Not all KPIs help attain alignment.* The model shows if the KPIs chosen are eligible for alignment. If with a certain set of KPIs chosen VS managers cannot attain alignment, the authors recommend rethinking the choice through application of HKT technology.
- ***Proposition 2***. *The time spent in attaining alignment can be quantified.* The model can help VS managers quantify how much time - and resources - will it take to attain alignment. Because alignment is a desired organizational state to be at when dealing with complex VS, it is worth working strategically towards it. This model can help better design strategic alignment seeking policies.
- ***Proposition 3.*** *VS effective goal achievement is a complex task and absolute goals might not be strategically advisable.* VS effective goal achievement might be more complex than a formulation of absolute corporate goals such as “Zero defects”, “Unit cost reduction” or “Market share growth”. The model makes implicit dynamic KPI relationships explicit. By quantifying the dynamic relationships between KPIs, this model helps VS managers better align their strategic efforts towards realistic equilibrium points, rather than trying to achieve unrealistic goals that might bring the overall system out of control.

There are several managerial implications that can be derived from the implementation of this **Nemawashi** Managerial Roadmap.

- First, this method is able to provide managers with insights regarding the VS alignment potential of any tern of KPIs related to VS. With a relatively limited amount of data, managers are able to discern if the coefficients describing (6) allow for VS alignment. This allows for a strategic re-adjustment of KPIs throughout the HKT process.
- Second, once the coefficients of the interaction matrix are iterated, this method allows for discovering attractors within the VS. These attractors would be represented by KPI POs that have a higher specific weight and play a more important role in the **Nemawashi** process than others.
- Third, this method allows for a dynamic description of the **Nemawashi** process. Being the coefficients of the VS r_i and a_{ij} known, equation (6) is fully described. As a result, managers are able to foresee the dynamic properties $\dot{x}_i$ and $\ddot{x}_i$ of the KPI system.

The limitations of this model and related further steps for future research are mainly three:

- ***Limitation 1.*** *Restriction of* ***Nemawashi*** *to WLP.* The WLP model is a **co-existence** model without a winner. In fact there are many other types of interaction models such as **exclusion** in which some PO excludes others or **mutual extinction** in which all POs lose. The authors believe that exclusion and mutual extinction are not a proper VS management because they might less likely lead to win-win situations and therefore consider solely the WLP model.
- ***Limitation 2.*** *Only three KPIs are analytically considered.* The model only shows the interaction of three KPIs and is therefore incomplete when attaining to describe whole HKT KPI ecological dynamics. Theoretically, the model does not establish any limitation to the number of VS related KPI under consideration. However, as the PO try to identify and prioritize the most relevant KPI, still it seems reasonable that the significant number of relevant KPIs are bounded as it happens with the 80/20 Pareto rule. Anyhow, there are two different aspects under consideration when dealing with scalability due to VS complexity increase:
    1) The first one is the necessary conditions for asymptotic stability. These require specific conditions as shown in (7), (8) and (9). These conditions can be analytically hard to define as the number of KPIs increases.
    2) The second aspect is related to the computational capability for adjusting the **A** coefficients so that the trajectories become closer to the ones identified during the initial steps. The decision will be based on minimizing a function cost defined as the additive squared of absolute differences between each trajectory based on solving the Ordinary Differential Equation (ODE) and the one estimated from the empirical observation period. The number of parameters to be determined is n^2+n, where n is the number of involved KPIs. The computational complexity is expected therefore to remain manageable, being the suggested number of individuals in the population ($500 \cdot \log(n^2)$) with 35-45% of crossover, 1-3% of mutation and 10-15% of elitism. The expected computation time scales as logarithmic rule. It is necessary to accentuate however that the genetic algorithm is a heuristic technique. This means that there is no guarantee about the exact solution found. Because of this some strategies repeat the evolution by starting randomly in order to increase solution´s resilience.
- **Limitation 3.** The model describes how the **Nemawashi** process works towards alignment, but does not describe why are **Nemawashi** and alignment desirable and what happens when the VS is optimized. In this ongoing research, the authors have purposely not deepen the analysis on why VS ought to be managed with a **Nemawashi** process and what happens when the continuous improvement process algorithm changes the process variables. The importance of these dynamic properties of the **Nemawashi** process shall be discussed in further research by the authors.

References

[1] Grant, R.M., 2010. Organization Structure and Management Systems: The Fundamentals of Strategy Implementation, in *Contemporary Strategy Analysis*, 7th ed., John Wiley & Sons, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom, p. 174-206.

[2] Cattani, G., Ferriani, S., Negro, G., Perretti, F., 2008. The Structure of Consensus: Network Ties Legitimation and Exit Rates of U.S. Feature Film Producer Organizations, *Administrative Science Quarterly* 53, p. 145-182.

[3] Schneider, M., Somers, M., 2006. Organizations as complex adaptive systems: Implications of Complexity Theory for leadership research, *The Leadership Quarterly* 17, p. 351-365.

[4] Cross, R.L., Singer, J., Colella, S., Thomas, R.J., Silverstone, Y., 2010. *The organizational network fieldbook: Best practices, techniques and exercises to drive organizational innovation and performance*, John Wiley & Sons.

[5] González-Díaz, L.A., Gutierrez, E.D., Varona, P., Cabrera, J.L., 2013. Winnerless competition in coupled Lotka-Volterra maps, *Phys. Rev.* E88, p. 1-6.

[6] Galbraith, J.R., 1974. Organizational Design: An Information Processing View, *Interfaces* 4, p. 28-36.

[7] Schuster, M., Kesler, G., 2011. Aligning Reward Systems in Organization Design: How to Activate the Orphan Star Point, *People & Strategy* 34, p. 38-45.

[8] Kates, A., Galbraith, J.R., 2007. *Designing your Organization. Using the Star Model to Solve critical design challenges.*, Jossey-Bass, San Francisco.

[9] Salado, A., Nilchiani, R., 2014. The concept of problem complexity, *Procedia Computer Science*, 28, p. 539-546.

[10] Friston, K.J., 1994. Functional and Effective Connectivity in Neuroimaging: A Synthesis, *Human brain mapping* 2, p. 56-78.

[11] Villalba Díez, J., Ordieres-Meré, J., 2015. Improving manufacturing operational performance by standardizing

process management., *Transactions on Engineering Management* 62(3) p. 351-360.

[12] Villalba-Diez, J., Ordieres-Meré, J., Nuber, G., 2015. The HOSHIN KANRI TREE. Cross-Plant Lean Shopfloor Management, in: *CIRP*. Presented at the *The 5th Conference on Learning Factories 2015*, Elsevier, Bochum, Germany, pp. 150–155.

[13] Linnea, C., 2009. Stable Coexistence of Three Species in Competition. (Examensarbete). LINKöPING UNIVERSITET, LINKÖPING, SWEDEN.

[14] Freedman, H.I., 1980. *Deterministic Mathematical Models in Population Ecology*, Marcel Dekker, INC., p. 92.

[15] Hofbauer, J., Sigmund, K., 1988. *Evolutionary games and population dynamics*, Cambridge University Press, Cambridge.

[16] Damelio, R., 2011. Chapter 5. Cross-Functional Process Map (aka Swimlane Diagram), in *The basics of process mapping*. CRC Press, FL, USA, p. 73-92.

[17] Henry, M., Stevens, H., 2009. 8. Multiple Basins of Attraction, in *A primer of ecology with R*. Springer Science+Business Media, New York, p. 227-254.

[18] Womack, J.P., 2013. *Gemba Walks*, Lean Enterprises Inst Inc, Cambridge, Massachusetts.