Science of Collaboration, Balancing vs. Sharing: A Mathematical, Physical and Economical View

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Abstract. Our study relates to artifacts bodies, also known as 3M&I-bodies, which consist of human, material/machine, monetary and informational components. On the basis of our recent works (2008, 2014, 2016), this paper reviews the lever principle of collaboration, which is the balancing vs. sharing problem in 3M&I-body systems, and discusses the collaboration and balancing science of multi-bodies in sharing from a mathematical, physical and economical point of view. The mathematical view is based on the Venn diagram of sets, the physical view is based on the principle of the lever in Archimedes' work, and the economical view is based on the profit equation. This issue was first raised in our research in Japan in 1983, and at that time was a gaming approach to the joint policy on order-selection (sales) vs. the switch-over (manufacturing) model in a job shop. This two-center problem was later discussed as the management game model (MGM) in 1999, and was summarized in Springer's OR/MS series in 2008. For multi-body systems, the paper discusses and develops the scientific fundamentals of the Follett-like classification as domination, compromise, integration and sharing in conflict types. Also, our original type "the invisible collaboration in SCM and A. Smith's economics under demand speed (sharing)" is introduced, and the central (ERP) vs. distributed (series/ parallel) type of multi-body in heterogeneity is comparatively discussed.

Keywords: Artifacts body, principle of lever, Follett's classification, central (ERP) vs distributed (SCM), d-balancing

1. INTRODUCTION

Our study relates to artifacts bodies, also known as 3M&I-bodies, which consist of human, material/machine, monetary and informational components. On the basis of our recent works (2008, 2014, 2016), this paper reviews the lever principle of collaboration, which is the balancing vs. sharing problem in 3M&I-body systems, and discusses the collaboration and balancing science of multi-bodies in sharing from a mathematical, physical and economical point of view.

Recently, S. Nof etc. (Nof et al., 2015) published an evolutional book on the engineering of collaboration from the perspective of e-work, business, and services with robotics. The book includes many types of process (procedure) modeling in cooperation with 3M&I-body artifacts. This issue was also raised in our ICPR paper in 1997 (Matsui et al., 1997).

Our collaboration studies began with the traditional problem of sales (demand) vs. manufacturing (supply) non-cooperation. This original issue is a gaming approach to the joint policy on order-selection (sales) vs. switch-over (manufacturing) model in a job shop in 1983 (Matsui, 1983).

This model was later proposed as the two-center problem, and was first discussed as a management game model (MGM) in 1999 (Matsui, 2002). Our work on the MGM model was summarized in 2008, and the main topic was also presented in a Japanese paper (2005) in 'Diamond Harvard Business Review' (Matsui and Fujikawa, 2005).

For multi-body systems, our paper discusses the Follett-like classification (Follet, 1949) in terms of domination, compromise, integration and sharing in conflict types. Furthermore, our original type "invisible collaboration in SCM (Matsui, 2010) and A. Smith's economics in 1759 (Smith, 1932) under demand speed (sharing)" is introduced, and the central (ERP) vs. distributed (series / parallel) type of multi-body in heterogeneity is comparatively discussed.

First, this paper reviews the traditional collaboration problem in business vs. manufacturing. Next, the basis of collaboration science is presented from a mathematical, physical and economical point of view. Throughout the paper, the principle of d-balancing is seen, in which d means the invisible hand of input types. It is here remarked that the phenomenon of balancing or invisible collaboration might be similar to the nonlocality of Quantum Mechanics in physics (spacetime).

2. COLLABORATION VS. BALANCING ISSUES

2.1 Traditional Problem at Business

In your company, do business and manufacturing really coexist? How can you attempt to measure the effective coexistence but not the conflict? The conflict in these two functions is a classic and unresolved problem.

In 1933, a business administration researcher named Mary Parker Follet presented a lecture in London (Follet, 1949). The topic on which she presented remains relevant in the twenty-first century. She discussed the functional relations between these sections in the form of "Separation of Planning Division," even though about 100 years have passed since Frederic Taylor's scientific management was generated. It is said that Follet was different, even though there was much criticism of his organization theory according to this function.

Professor Benson Shapiro at the Harvard School of Business and Professor Davis at the University of Georgia presented the interface problem of marketing and manufacturing in 1977, and contributed their ideas to the 'Harvard Business Review' and 'Interface' magazines (Shapiro, 1977).

This was about 30 years ago, but those who conducted research on marketing, including Philip Kotler (1965), also admitted the importance of correspondence to be able to achieve harmony between sections. In 1993, cooperative issues were summarized by Eliashberg and Sleinberg.

Generally, the marketing section is interested in the maximization of sales, and, conversely, the manufacturing section is interested in the minimization of cost. However, the difference between sales and costs is not maximized if there is no cooperation in labor. This problem was recently discussed and developed by Matsui etc. in 1983.

2.2 Two-center Types and d-balancing

How should one resolve the conflict between business and manufacturing and how should one achieve collaboration? We are calling this the "Two-Center Problem." This problem is where Follet also positively admits the meaning of the conflict, and it is necessary to quickly resolve the problem so that management and society may develop. To resolve this conflict, the following four approaches are presented in Table 1.

(a) Summary of two-center types

The relationship between sales (A) and production (B) centers should be classified into domination, compromise and integration (Matsui, 2002; Follet, 1949). Table 2 shows a classification of integration and a relational two-center model in a broad sense. In Table 2, the notations A and B are a pair-set, H(X) or H(Y) is a negative entropy, I(X,Y) is mutual information, and H(X⊗Y) is joint information.

In Table 2, it is noted that the bottleneck concept is a special case of a two-center model. Furthermore, the sharing type is added here. This is seen at VMI (vender-managed inventory) in Table 1.

Furthermore, the additional types are $A \cap B = \emptyset$ and $A \cap B^C$, which are characterized as a class of invisible collaboration and VMI-sharing, respectively. The former is related to the win-win principle in the SCM and to the invisible hand in A. Smith's economics. The latter was recently related to the sharing of community and economics.

(b) d-balancing class

Two principles of medium balancing are presented and considered here. Initially, the d-balancing problem is seen on the upper level of the two-level scheme in the hierarchy. This main problem can be broken down into two sub-problems:

$$F_i(I_i) = \bar{\beta}_i, \qquad i = 1, 2, \dots, n \quad (1)$$

in the respective body of entity i in the Newsboy problem. Matsui's point, $\bar{\beta}_i$, is based on the so-called Chameleon's criteria.

Currently, the following condition is considered according to the demand speed (cycle time), d ($0< d<1$), and the exponential service with the mean, m_i (supply speed). That is,

$$G_i(d) = 1 - \exp\left(-d/m_i\right) = \bar{\beta}_i, \qquad i = 1, 2, \dots, n \quad (2)$$

and the demand speed, d, is as follows:

$$d = -m_i \ln\left(1-\overline{\beta_i}\right). \qquad (3)$$

Table 1 Four types of two center models (Matsui, 2008)

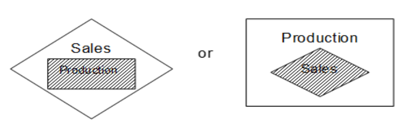
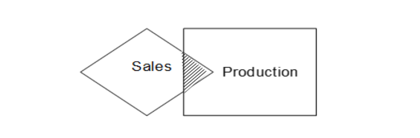
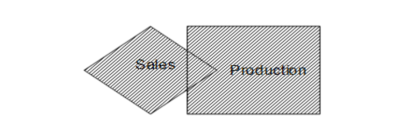
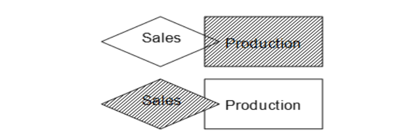
Types	Patterns	Management
Domination		TOC/ divisionalization
Compromise		Trade/ distributed (non-cooperation)
Integration		Collaboration/ centralized (cooperation)
Sharing		VMI/ remote

Table 2: Integration and two-center (added on Matsui, 2002)

Integration	Demand/supply	Sharing	Set relation	Constraints	2-centered model
Domination	vertical	occupancy	$A \subset B$ or $B \subset A$	$H(X)$ or $H(Y)$	bottleneck (TOC)
Compromise	Trade	sharing	$A \cap B$	$H(X \otimes Y)$	strategic/ gaming
Integration	collaborative	demand/ unification	$A \cup B$	$I(X,Y)^*$	MGM
Sharing	chain	inventory/ seat	$A-B, B-A$ or $A \Delta B$	$H(X-Y), H(Y-X)$ or $H(X \Delta Y)$	VMI/remote

$*I(X,Y) = H(X) + H(Y) - H(X \otimes Y)$

In d-balancing, the following relation is also obtained from (3):

$$m_i \ln\left(1-\overline{\beta_i}\right) = m_j \ln\left(1-\overline{\beta_j}\right), \ i \neq j. \qquad (4)$$

In particular, for Poisson service, the optimal condition is

$$F_i(I_i) = \sum_{i=1}^{I_i} P(d; m_i) = 1-\overline{\beta_i}, \ i = 1, 2, \dots, n \qquad (5)$$

where $P(\cdot)$ is a Poisson type distribution.

These relationships can generally be outlined by the pitch diagram in line balancing. From this pitch diagram and Matsui's equation $(W = ZL)$, the balance equation is

$$\sum_{i=1}^{I_i} MI_i = nZ, \qquad (6)$$

and the second balancing principle is

$$L\sqrt{ZL} < \sum MI_i < ZL = W. \qquad (7)$$

from (6) and the classic inequality.

Finally, it is noted that the so-called invisible collaboration would correspond to the balancing state for any d (>0), demand speed (invisible hand).

3. VIEWS OF COLLABORATION SCIENCE (Ⅰ)

3.1 Domination Class

The mathematical view is based on a Venn diagram of sets, and on a definition in the multi-body collaboration class. The physical view is based on the principle of the lever and on specific gravity in physics (Archimedes' work). The economical view is based on the principle of balancing in 3M&I-body science. In these views, one sees the principle of balancing in collaboration issues in Matsui's equation (2008) from 1977.

In the domination class, the three aspects of views are seen in Figures 2 and 3 from Matsui (2016) etc. as follows:

(a) Mathematical (set) view

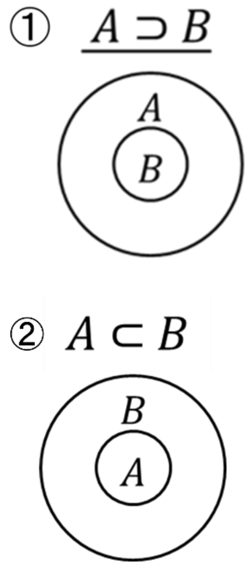
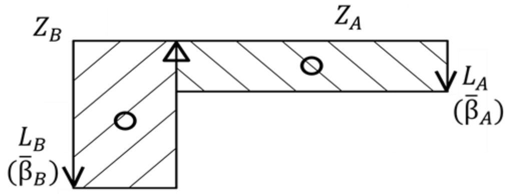
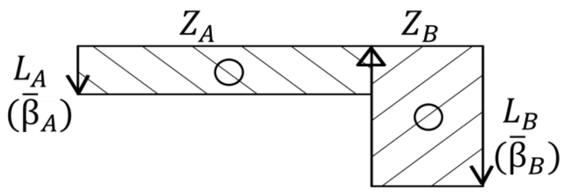


Figure 1: dominance/occupation (A⊃B and A⊂B)

(b) Physical (lever) view



③ $Z_B\bar{\beta}_B = Z_A\bar{\beta}_A$ (revenue)



④ $Z_A\bar{\beta}_A = Z_B\bar{\beta}_B$ (revenue)

Figure 2: Principle of lever in revenue

(c) Economical (value) view

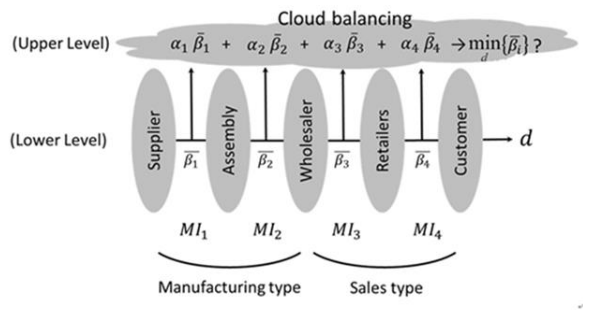


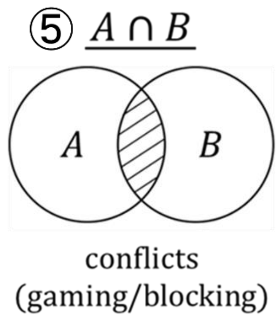
Figure 3: Body-balancing system of supply chain economics in (Matsui, 2014).

An optimal condition (balancing) is assumed from the classic inequality and Matsui's equation ($W = ZL$) (Matsui, 2015) as follows:

Hypothesis: $\alpha_1\bar{\beta}_1 = \alpha_2\bar{\beta}_2 = \cdots = \alpha_n\bar{\beta}_n = (W = ZL)$. (8)
In (8), Z and L correspond to a_i and $\bar{\beta}_i$, respectively, and W means a balancing value at the equilibrium.

3.2 Compromise Class (A～B)

In the compromise class, the three aspects of views are similar to **3.1** and are presented as follows:
(a) Mathematical (set) view



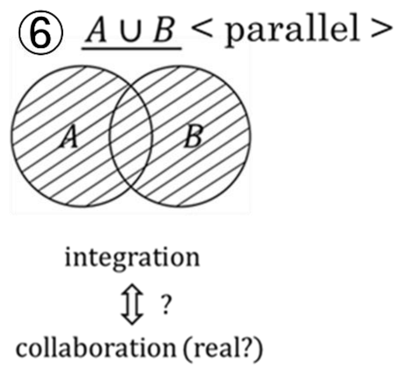
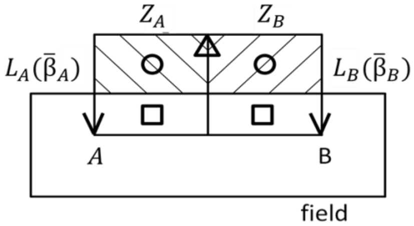
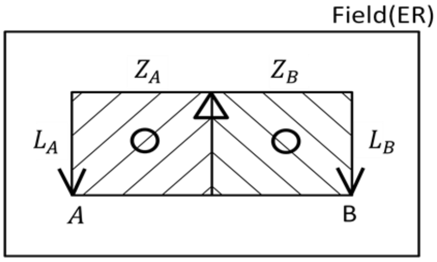


Figure 4: Conflicts and integration (A ∩ B and A ∪ B)

(b) Physical (lever) view



⑦ $Z_\mathrm{A}\bar{\beta}_\mathrm{A} = Z_\mathrm{B}\bar{\beta}_\mathrm{B}$ (revenue)



⑧ $Z_\mathrm{A}\mathrm{L}_\mathrm{A} = Z_\mathrm{B}\mathrm{L}_\mathrm{B}$ (cost)

Figure 5: Principle of lever at specific gravity

(c) Economical (value) view (Matsui, 2014)

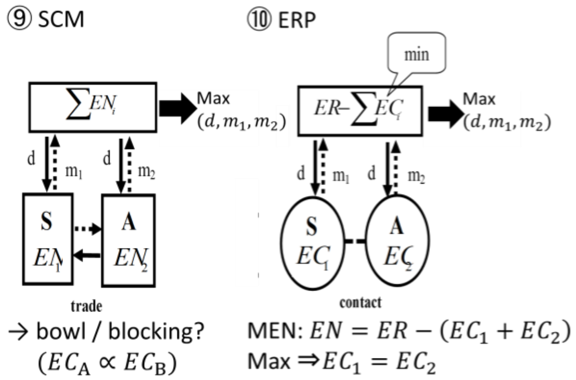


Figure 6: SCM (series) vs. ERP (parallel) in MGMs

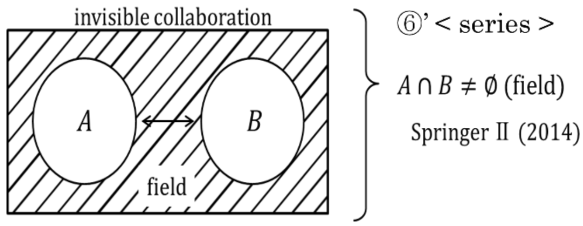
In this class, the win-win strategy is different to the series vs. parallel type. The former is profit-even, and the latter is cost-even.

4. VIEWS OF COLLABORATION SCIENCE (Ⅱ)

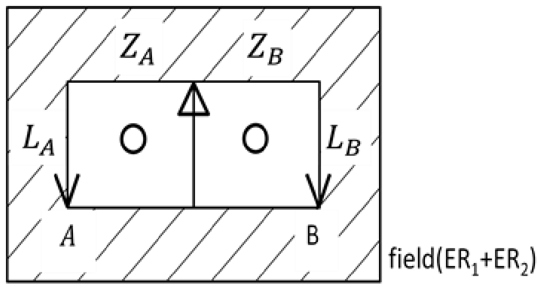
4.1 Integration Class

In the integration class, the three aspects of views are seen as follows:

(a) Mathematical (set) view

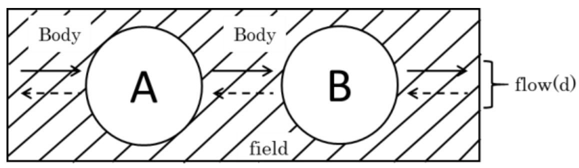


(b) Physical (lever) view



$Z_\mathrm{A}\mathrm{L}_\mathrm{A} = Z_\mathrm{B}\mathrm{L}_\mathrm{B}$ (profit)

(c) Economical (value) view (Matsui, 2016)



"*Jyukyu*" invisible collaboration

d: demand speed/cycle time (sharing)

⟶ : material, ⇠ : information

(A, B : heterogeneous bodies)

$$DEN: EN = (ER_\mathrm{A} - EC_\mathrm{A})^+ + (ER_\mathrm{B} - EC_\mathrm{B})^+$$

$$\text{Max} \Rightarrow EN_\mathrm{A} = EN_\mathrm{A} \quad \langle \text{Win} - \text{Win} \rangle$$

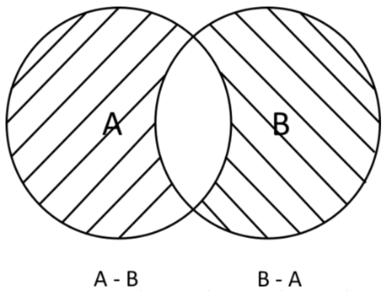
Figure 7: Invisible chain and collaboration: (a), (b) and (c)

In this class, the following is noted. In the physical view, the win-win strategy is the balancing of costs or profits. However, in the economical view, it is not the direct sum of profits, but the dual sum or balancing of profits.

4.2 VMI-sharing Class

In the VMI-sharing class, many types of sharing have been seen recently in community economics. These views of three aspects are original and as follows:

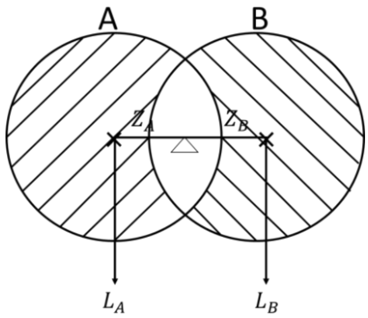
(a) Mathematical (set) view



$(\mathrm{A}-\mathrm{B})$ or $(\mathrm{B}-\mathrm{A})$

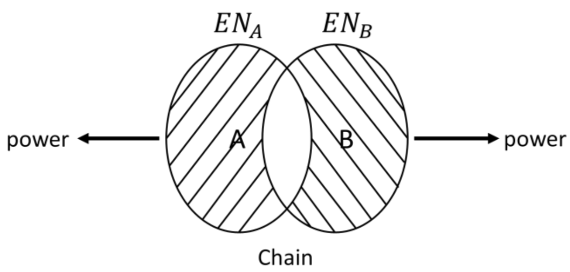
$(\mathrm{A}-\mathrm{B}) \cup (\mathrm{B}-\mathrm{A})$ $(=\mathrm{A}\Delta\mathrm{B})$

(b) Physical (lever) view



$Z_{\mathrm{A}}\mathrm{L}_{\mathrm{A}} = Z_{\mathrm{B}}\mathrm{L}_{\mathrm{B}}$ (weight/cost)

(c) Economical (value) view



Strength of chain (value chain):

$EN_{AB} = EN_{\mathrm{A}} \times EN_{\mathbf{B}} \Leftrightarrow \min(EN_{\mathrm{A}}, EN_{\mathrm{B}})$

<specific gravity / profit>

Figure 8: Visible chain and sharing: (a), (b) and (c)

In this class, the following is noted. In the physical view, the weight of the chain (sub-optimal) corresponds to the amount or balancing of costs. However, in the economical view, the strength of the chain (total optimal) corresponds to the max-product of profits.

5. CONCLUSIONS

In this paper, the collaboration and balancing science of multi-bodies were discussed from a mathematical, physical and economical point of view. These three views are consistent with the collaboration vs. balancing principle, and the arrangement of the central (ERP) vs. distributed (series/parallel) type in heterogeneity is comparatively presented and considered.

In conclusion, this paper presented the basis of collaboration science, and the balancing principle in Matsui (2016) is positioned as the main principal in the 3M&I-body system. The additional subjects are the quantitative and procedural steps toward the analysis and design of artifacts collaboration. In the near future, our study would be useful to the science and engineering design of robots in organizations and societies in connection with the sandwich principal.

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