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Use of Human Big Data to Help Improve Productivity in Service Businesses

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OVERVIEW: While initiatives that use big data to improve productivity have become commonplace in the industrial sector, the quantitative assessment of the relationship between worker actions and organizational results and its use to make improvements has proved difficult in service businesses and knowledge work. Hitachi has devised a technique that uses wearable sensors and AI to identify action characteristics that influence organizational KPIs. This article describes a demonstration project at The Bank of Tokyo-Mitsubishi UFJ, Ltd. that involved a comprehensive study of the relationship between organizational KPIs and action characteristics to identify those action characteristics that were effective at improving KPIs for each attribute and situation. This succeeded in identifying the people and actions that contribute to the organization. Hitachi intends to use this technique to build management support systems that enable teams to perform to their full potential.

INTRODUCTION

WHILE tertiary industry accounts for approximately 70% of both gross domestic product (GDP) and employment in Japan, the labor productivity growth rate has been a poor 0.8% (from 1995 to 2003), placing Japan 19th out of the 27 members of the Organisation for Economic Co-operation and Development (OECD)[1]. Because services generate value through interactions between people rather than in the form of physical goods, productivity improvement requires the analysis of people and the acquisition of knowledge.

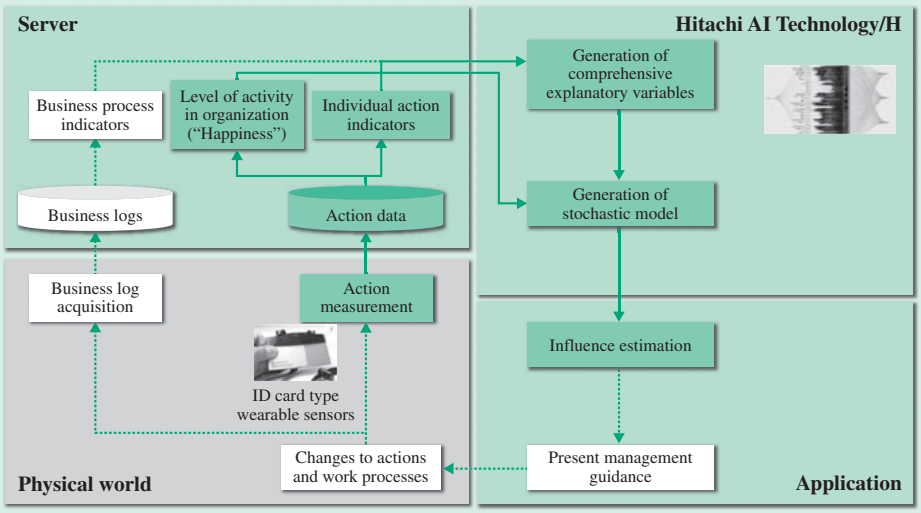
Use of big data has attracted attention in recent years, and while productivity improvements are being made in the industrial sector, the quantification of worker actions and organizational results in the service sector has proved difficult. This is because value is created through people with different roles working together as teams, meaning that improvements in individual productivity do not necessarily lead to improvements in overall productivity as they would with a machine. As a result, managers need to make management decisions without any means for determining which actions by which people are contributing to the overall organization.

This article describes how Hitachi set about quantitatively evaluating the relationships between worker actions and organizational results with the aim of building systems that will present management guidelines on how to get teams to perform to their full potential. This involved the study of a management support system that makes comprehensive use of three methods in the form of human big data. These methods are: identification (ID) card type wearable sensors that Hitachi developed previously, an indicator of the level of activity at an organization ("happiness"), and Hitachi Artificial Intelligence (AI) Technology/H. A demonstration project was conducted at The Bank of Tokyo-Mitsubishi UFJ, Ltd. to evaluate the viability of this system by identifying action characteristics for each worker attribute and situation.

MANAGEMENT SUPPORT SYSTEM

Overall Concept

The aim is to build a system that can analyze data on business processes and provide managerial staff with management guidelines. Specifically, Hitachi is seeking to provide quantitative criteria for deciding what each staff member should be focusing on, taking account of external factors such as the weather and events. This is to be achieved by establishing a sustainable cycle that provides daily and attribute-specific management guidelines by using wearable sensors to measure worker activity and AI to generate stochastic models (see Fig. 1).



ID: identification

Fig. 1—Conceptual Diagram of a Management Support System. Hitachi has built a system that uses AI to analyze human behavior data and business logs collected from the physical world and to identify the best action plans for improving the organization's overall KPIs with respect to individual attributes and situations. The parts indicated by dotted lines are outside the scope of the demonstration project described in this article.

Measurement of Actions by Individuals —ID Card Type Wearable Sensors—

ID card type wearable sensors are used to measure worker actions. These devices use a built-in infrared sensor to detect communication between people and an accelerometer to detect physical movements. This information is used to obtain work characteristics indicators, such as the quantity and quality of office worker communication (whether it is one-way or two-way) and the length of time spent on uninterrupted desk work (see Fig. 2)[2].

Measuring the State of the Organization —Level of Organization Activity ("Happiness")—

The level of activity in an organization is a quantitative indicator of the "happiness" at that organization obtained from the pattern of people's physical movements. It is calculated from the variability in the duration of periods of continuous activity, using the accelerometer contained in the ID card type wearable sensor to determine whether a person is active or sedentary. It has been demonstrated that the level of

Category	Indicator	Definition
Duration of interaction (min)	Total time	Time during which interaction with at least one other person is detected
	Two-way	Time during which two-way conversation is in progress
	Pitcher	Time during which subject is speaking
	Catcher	Time during which subject is listening
Number of interactions (number of instances of each category of interaction duration)	(a) Continuing for < 5 min	Number of short conversations (greetings or passing on a message)
	(b) Continuing for 5 < 15 min	
	(c) Continuing for 15 < 30 min	Number of long conversations (such as meetings)
	(d) Continuing for ≥ 30 min	
Duration of desk work (min)	Total duration of desk work	Time during which subject does not interact with others and has minimal physical movement
	Maximum duration of continuous desk work	Longest period of uninterrupted desk work during the day
Number of instances of desk work (number of instances of each duration category)	(a) Continuing for < 5 min	Number of times desk work is interrupted (by being spoken to, going for a walk, etc.)
	(b) Continuing for 5 < 15 min	
	(c) Continuing for 15 < 30 min	Number of times desk work continues for a long period with few interruptions
	(d) Continuing for ≥ 30 min	
Length of time sensor is worn (min)	Length of time sensor is worn	Time measured by ID card type sensor (in the case of office work, this is the office's working hours)

Fig. 2—List of Action Indicators for Office Workers. Hitachi has defined indicators for interactive communication and desk work.

activity in an organization is correlated with daily productivity, and it has been suggested for use as a daily key performance indicator (KPI), even in services that find it difficult to quantify the state of the organization[3]. With reference to this, this article uses the level of activity in an organization as a KPI for that organization.

Uncovering Relationships between Individuals and the Organization—Hitachi AI Technology/H—

The system uses Hitachi AI Technology/H to analyze quantitative data. Hitachi AI Technology/H generates explanatory variables of various types by exhaustively combining action indicators and other information (attributes, events, and so on), and then determines which of these indicators are relevant to the target variable. When the target variable has macro data granularity (organization-wide indicators, for example) and the explanatory variables have micro granularity (indicators that relate to individuals), a stochastic model is used to determine which actions by an individual influence the organizational indicators.

In this way, when organizational KPIs are set as target variables, Hitachi AI Technology/H can perform an exhaustive search to identify which individual action indicators are relevant to the KPIs[4].

DEMONSTRATION PROJECT AT THE BANK OF TOKYO-MITSUBISHI UFJ

The first demonstration project was conducted at Hitachi's partner, The Bank of Tokyo-Mitsubishi UFJ, Ltd., to verify the viability of implementing the concept described in the chapter above.

Purpose of Demonstration Project

The demonstration project sought to verify the following.

(1) Whether the system can identify which individual action indicators explain organizational KPIs, and then order them by priority.

(2) Whether the system can obtain action indicators that take account of external factors (such as weather and events) that are outside the control of the people in the workplace.

Project Overview

Data was collected from the ID card type wearable sensors as follows:

Department: Headquarters planning department (office work)

Measurement period: Three weeks

Subjects: Approximately 40 people (three groups, each with 10 people or more)

Method of Analysis

The analysis was conducted using the following procedure.

(1) Action indicators for office workers

The office worker action indicators listed in Fig. 2 were used. The nature of one-to-one communication was categorized as "two-way," "pitcher," or "catcher" based on the extent of physical movement by the two parties, and utilized the number of interactions categorized according to duration, which reflect the type of conversation (greeting, passing on a message, long discussion, and so on). The maximum duration of uninterrupted desk work and the number of each duration of uninterrupted desk work were calculated by treating as interruptions those instances in which interaction was detected or the degree of physical movement became large.

(2) Calculate level of activity in the organization

The level of activity in the organization was calculated for each day and group.

(3) Identify indicators

Taking the level of activity in the organization on each day and for each group as target variables, analysis determined which individual action characteristics were associated with variations in the daily value. To generate the indicators, the action indicators (continuous values) were classified into two categories depending on whether they were above or below the median. These indicators were then used to generate compound indicators made up of all possible combinations of "attributes and action indicators" and "external factors and action indicators," and a t-test with a significance criterion of $p < 0.05$ was used to identify those action indicators that made a significant difference to the level of activity in the organization.

DEMONSTRATION PROJECT RESULTS

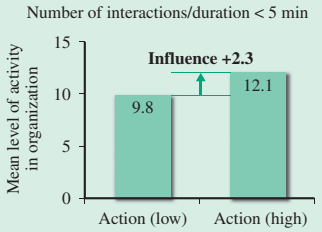
Simple Analysis

Before conducting the analysis using the compound indicators, the relationship between the individual action indicators and the level of activity in the organization were analyzed [see Fig. 3 (a)]*. This analysis satisfied $p < 0.05$ for the department being studied and found

* The experimental data shown in this article (Fig. 3 to 6) is a mock up for presentation purposes. However, the knowledge obtained is the same as that achieved in practice.

Action indicators		Mean level of activity in organization		Influence (difference in mean values)	Significance (p value)
		Action (low)	Action (high)		
Duration of interaction	Total time	10.4	11.6	1.2	0.88
	Two-way	9.3	11.8	2.5	0.11
	Pitcher	11.6	11.4	−0.2	0.11
	Catcher	10.6	12.0	1.4	0.85
Number of interactions	Continuing for < 5 min	9.8	12.1	2.3	**0.02**
	Continuing for 5 < 15 min	11.4	11.4	0.0	0.62
	Continuing for 15 < 30 min	9.5	12.4	2.9	0.35
	Continuing for ≥ 30 min	12.0	10.8	−1.2	0.58
Duration of desk work	Total time	11.5	10.4	−1.1	0.07
	Maximum duration of continuous work	11.0	11.5	0.5	0.78
Number of instances of desk work	Continuing for < 5 min	10.7	10.8	0.1	0.41
	Continuing for 5 < 15 min	11.8	10.8	−1.0	0.32
	Continuing for 15 < 30 min	10.6	11.4	0.7	0.40
	Continuing for ≥ 30 min	11.0	10.6	−0.4	0.86
Length of time sensor is worn		10.1	11.5	1.4	0.32

(a) Relationship between magnitude of all action indicators and the mean level of activity in organization



(b) Difference in levels of activity in the organization on days when the number of short interactions (less than five continuous minutes) was high and low

Fig. 3—Mean Value of Level of Activity in the Organization for Each Category of Action Indicator Values.
The level of activity in the organization was higher on days with a large number of short interactions (greetings or passing on a message) than on days with a low number (with a significance of $p < 0.05$). The "influence" means the expected change in the level of activity in the organization when actions are changed.

a relationship with the "number of interactions lasting less than five minutes" action indicator. The mean level of activity in the organization was 12.1 on days with a large number of short interactions (greetings, passing on a message, and so on) and 9.8 on days when the number of such interactions was low. This difference of +2.3 is called the "influence." The "influence" is the change in the level of activity in the organization that is expected to result from a change in action, such that the larger its absolute value the more a change in action is expected to influence the level of activity in the organization [see Fig. 3 (b)]*.

Action characteristic		Duration of interaction				Number of interactions				Desk work		Number of instances of desk work				Length of time sensor is worn
		Total time	Two-way	Pitcher	Catcher	Continuing for < 5 min	Continuing for 5 < 15 min	Continuing for 15 < 30 min	Continuing for ≥ 30 min	Total time	Maximum duration of continuous desk work	Continuing for < 5 min	Continuing for 5 < 15 min	Continuing for 15 < 30 min	Continuing for ≥ 30 min	
Status	Management A	-	-	-	-	1.5	-	-	-	-	-	-	-	-	-	-
	Management B	-	1.5	-	-	-	-	-	1.1	-	-	-	-	-	-	-
	Staff member	0.9	-	-	-	1.6	2.2	-	-	-	1.8	-	-	-	-	-
Age	20s	-	-	1.3	-	-	-	-	2.1	-	-	-	-	-	−0.7	-
	30s	1.6	1.8	-	1.5	2.8	-	-	-	-	-	-	-	-	-	0.8
	40s or older	-	2.0	-	-	1.9	-	-	-	−1.8	-	-	-	-	-	0.3
Gender	Male	-	1.7	-	-	1.2	-	-	-	-	-	−1.5	-	-	-	-
	Female	1.1	2.1	-	-	1.8	-	-	-	-	-	-	-	-	-	-
Job	Job A	2.1	-	-	-	1.2	-	-	-	−1.0	-	-	-	-	-	-
	Job B	2.0	-	-	-	1.7	-	-	-	-	-	-	-	-	-	-
	Job C	-	-	-	-	-	-	-	-	-	-	-	0.3	-	1.7	-
No. of years at department	Low (< 3.5)	-	0.7	-	-	1.4	-	-	-	-	-	-	0.3	-	2.5	-
	High (≥ 3.5)	-	-	-	0.6	0.8	-	-	-	−1.7	-	-	-	-	−1.6	-

Fig. 4—Results of Action Characteristics Analysis for Different Attributes.
The table shows the results for all combinations of attributes and action indicators. Influence values are only shown for attributes in the case of indicators for which there is a significant ($p < 0.05$) difference in the level of activity in the organization between days with a high number of actions and days with a low number. A positive influence value means that a high number of actions for that attribute is associated with a high level of activity in the organization, whereas a negative value means the opposite. The larger the absolute value of the influence, the higher the priority. Action indicators with an absolute influence value of 2.5 or more are highlighted in bold frames.

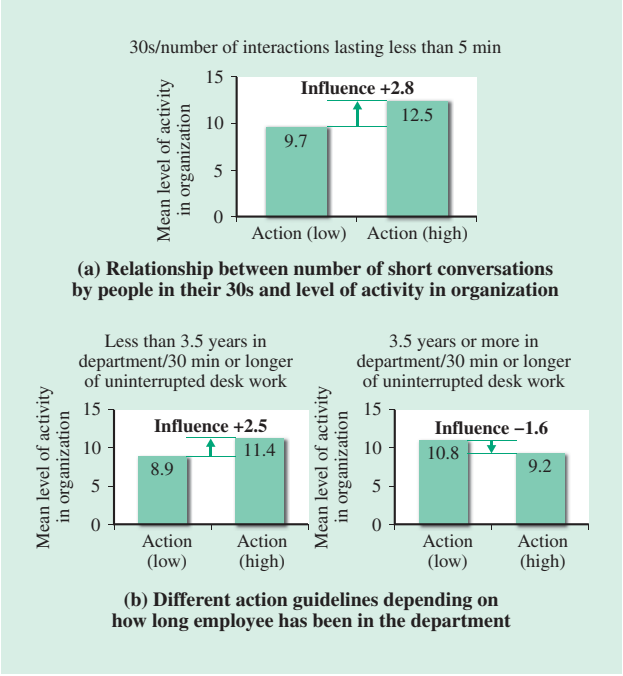


Fig. 5—Example of Action Characteristics Analysis for Different Attributes.
(a) The level of activity in the organization is higher by 2.8 on days on which people in their 30s had frequent short conversations such as greetings or passing on a message.
(b) Opposite guidelines were obtained for uninterrupted desk work time depending on how long the employee has been in the department.

Analysis of Action Characteristics by Attribute

A t-test of the compound indicators formed from the combination of "attributes and action characteristics" found influence values for indicators with $p < 0.05$ similar to those described above (see Fig. 4)*. This can be used to identify relationships (with a significance of $p < 0.05$) between variations in the level of activity in the organization and the magnitude of actions with specific attributes, and to list these actions in order of priority based on the absolute value of their "influence."

The overall trend was that indicators that relate to the duration of interactions, particularly the number of short interactions (greetings, passing on a message, and so on), has a positive correlation with numerous attributes, which is to say that the level of activity in the organization was higher for higher values of the indicator. On the other hand, the total time spent on desk work was found to have a negative correlation, meaning that the level of activity in the organization was higher for shorter desk work times.

An individual finding with a high level of influence was that the level of activity across the entire organization was high when people in their 30s had short and frequent conversations. A difference in action indicators was also found between new recruits who had been in the department for up to 3.5 years and long-term employees who had been there for 3.5 years or more, where it was better for the former to have long desk work durations (30 minutes or longer), and for the organization as a whole, it was desirable if the situation for the latter group included desk work that was split up into periods of less than 30 minutes due to interruptions such as being consulted by other staff (see Fig. 5)*.

Analysis of Action Characteristics by Situation

The demonstration project chose whether or not a social gathering was to be held after work as an example of an external factor outside the control of the people in the workplace. An analysis of the relationship between the level of activity in the organization and the compound indicators formed from the combinations of "social gathering (day of gathering, day after gathering, normal day) and action indicators" found that the level of activity in the organization could be increased on days with a social gathering if two-way conversations were longer, the frequency of short conversations was higher, and the frequency of long conversations was lower. On the

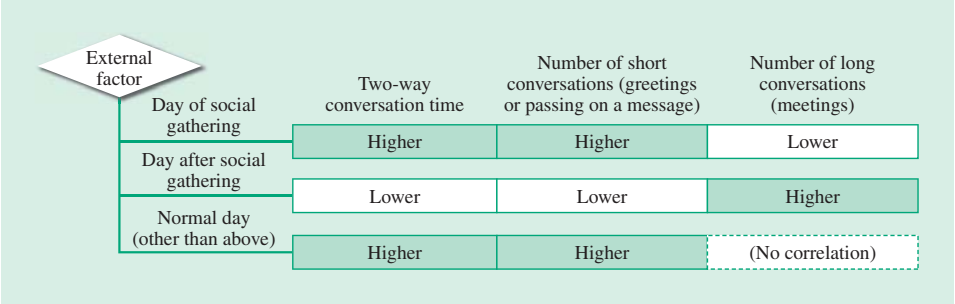


Fig. 6—Results of Action Characteristics Analysis for Different Situations (Sample). The results show that the measures for increasing the level of activity in the organization are different depending on external factors (day of gathering, day after gathering, normal day).

other hand, the opposite result was found for the day after a social gathering. That is, the level of activity in the organization was higher if two-way conversations were shorter, the number of short conversations was lower, and the number of long conversations was higher (see Fig. 6)*. The interpretation of this finding is that, because people are still tired on the day after a social gathering, productivity is higher when discussions are held over an extended period of time rather than working in short time intervals. Hitachi also concluded that, if data covering a long period of time was available, it would be possible to adopt a more detailed classification of external factors and determine action guidelines for individual factors, such as the weather, timing, and whether important customers are visiting or not.

CONCLUSIONS

The demonstration project described above succeeded in identifying action indicators for specific attributes and situations that are associated with the level of activity in the organization. This included the discovery, described above, of action characteristics for staff members who contribute indirectly to the organization, even though this is detrimental to their own productivity, as indicated by the finding that interruptions to the work of experienced staff raised the productivity of the organization as a whole. This suggests that it is practical to build management support systems that take account of indirect contributions that have not been assessed in the past. Hitachi intends to undertake further trials and testing as it works to implement such systems.

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