Solution Concept for Improving Work Efficiency in Nursing Homes

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Abstract: Regarding the decrease in social welfare spending and the growth of elderly population in Japan, for nursing homes, they need to increase occupancy rate by improvement of service quality to prevent decrease in business earnings, in which work efficiency improvement and human resource development are essential. The purpose of this paper is to develop a solution that assists nursing homes to improve the work efficiency. Frist, we established a solution concept. Then, to verify the solution concept, we carried out a proof of concept (PoC) in a paid nursing home along with Hitachi High Technologies Corporation (HHT). As a result, we discovered some places that can be improved in nursing care work and proposed some measures in the improvement plan. It is predicted that the total work time will decrease by 14.6% if the measures are introduced. We obtained a good prospect for the solution concept.

Keywords: Nursing Homes, Human Sensing Technologies, Business Microscope Sensor System, Work Efficiency

1. Introduction

Japan is one of the most aging countries in the world when considering the aging rate or the proportion of the aged population, and the percentage of people aged 65 and over will reach 38.8% by the year 2050 [1]. Along with the increase in the population that needs nursing care, the market scale in nursing care business in Japan will increase to 15.2 trillion yen (in 2025) from 6.4 trillion yen (in 2007) according to Mizuho's investigation [2].

On the other hand, it is predicted that social security expenditure will increase to 149 trillion (in 2025) from 109 trillion (in 2012) [3]; the increase rate of which is beyond that of economic growth. To improve the fiscal balance in Japan, the amount of increase in social welfare spending has been decreased by the government. Medical and long-term care fee is one of the areas where this has happened. In the revision of long-term care fees, the nursing care compensation of nursing care vendors decreased by 2.27% while the salary of employees in nursing home vendors increased by 1.65% [4].

Because of the revision of long-term care fees, nursing homes' income from every occupant decreased. For nursing homes, they need to increase occupancy rate by improvement of service quality to prevent decrease in business earnings, in which work efficiency improvement and human resource development are essential. Although many products and services have been developed for the nursing industry [6]-[10], in view of the present situation of one nurse to three aged people, it is essential to innovate with information technology (IT) to improve efficiency and enforce human resource development in the nursing home.

Hitachi is taking the opportunity to develop solutions for nursing homes to prevent decrease in business earnings through improving work efficiency by IT. In the background, Hitachi High-technologies Corporation (HHT) is engaged in creating new business through making full use of human sensing technologies such as business microscope (BM) sensor systems and optical topography. As part of new business creation, HHT is planning to develop human sensing and data visualization technology and apply it to nursing care businesses. Thus, we begin to develop the solution to improve work efficiency in nursing homes, cooperating with HHT and nursing homes.

The objective of this research is to establish a concept for the solution to improve work efficiency in nursing homes. After the solution concept establishment, we verified the solution concept through carrying out a PoC. In the implementation of PoC, we developed a solution core called nursing home visualizer. In this paper, we will introduce the solution concept, the nursing home visualizer and the process of the PoC.

2. Solution Concept

To improve work efficiency in nursing homes, it is necessary to clarify the points that can be improved in nursing care work and make an improvement plan based on them. Therefore, we established a solution concept for nursing care business consulting to improve work efficiency.

2.1 Solution Concept Definition

The solution to improve work efficiency in nursing homes is made up of four steps (Figure 1). First, consultants set up hypotheses for improvement in work efficiency in nursing homes. Then, they collect staff member behavior data using a human sensor system. Next, they verify and specify the hypotheses made in Step 1. Finally, they establish a work efficiency improvement plan.

In Step1, consultants set up hypotheses for improvement in work efficiency in nursing homes. If consultants do not understand the actual situation of nursing homes, it is difficult to set up proper hypotheses, so, two general methods such as questionnaire surveys and ethnographic investigation are introduced to help consultants set up hypotheses.

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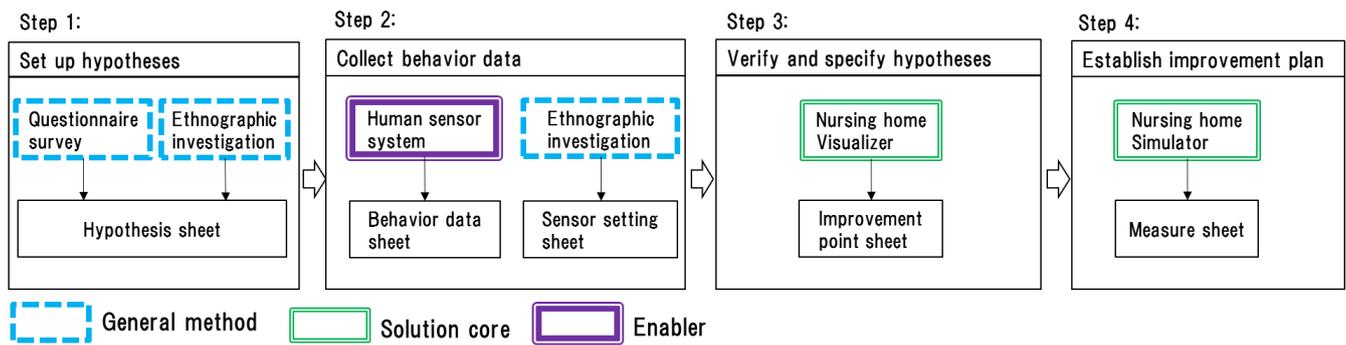†3 Hitachi Life, Ltd.

Figure 1 Solution Outline

In Step2, consultants collect data to verify the hypotheses. Because staff member behavior is the main factor to affect work efficiency, we use a human sensor system (e.g. business microscope (BM) sensor system) as an enabler in our solution to collect staff member behavior data. The way to set the sensor system is related to data collection precision, so it is necessary to decide how to set the human sensor system based on the ethnographic investigation result.

In Step 3, to help consultants verify and specify hypotheses, a solution core called nursing home visualizer is used to visualize the data collected in Step2. The nursing home visualizer can visualize staff member behavior data from many viewpoints, so it can help consultants to discover concrete problems in nursing care work.

In Step 4, consultants establish a work efficiency improvement plan based on the concrete problems discovered in Step 3. To see the effect of measures from a quantitative view, which is directly related to the manager's decision-making, a solution core called nursing home simulator is used to simulate the return on investment (ROI) of all the measures. It will help consultants to make better improvement plans.

In conclusion, the implementation of the solution concept includes two general methods (questionnaire survey and ethnographic investigation, two solution cores (nursing home visualizer and simulator) and an enabler human sensor system.

2.2 Problems and Approaches

The problems and approaches we focused on in every step are as follows.

(1) In Step 1, general methods such as questionnaire survey and ethnographic investigation are used. To carry out them better, it is essential to make full use of domain knowledge of nursing homes. Therefore, we will make a guideline including the format of investigation sheets and the way to carry out the investigations.

(2) In Step 2, it is necessary to determine what kind of sensor system is used to collect behavior data and how to guarantee the measurement precision when setting the sensor system. In this research, at the request of HHT, BM sensor system is used to collect staff member behavior data. We will give the format of ethnographic investigation for sensor system precision validation and make a guideline for setting BM system in nursing home.

(3) In Step 3, a solution core called nursing home visualizer is used for verifying hypotheses. However, regarding of dependency on domain knowledge of the nursing home and the sensor system used in Step 2, visualization tools in the market cannot directly visualize the data collected in Step 2. Therefore, taking account of domain knowledge of the nursing home, we developed a nursing home visualizer, which can visualize the data from many viewpoints.

(4) In step 4, a solution core called nursing home simulator is used for making improvement plan. In view of the same situation as the nursing home visualizer, we need to develop it, leveraging domain knowledge of nursing home and experiences of cyber PoC.

3. Nursing Home Visualizer

As mentioned above, in Step3 of the solution, to help consultants verify and specify hypotheses, we developed a nursing home visualizer as a solution core. In this chapter, we will introduce the nursing home visualizer.

3.1 Requirement Definition

To determine the requirements of the visualizer, first, we used the "onion model" [5] to identify stakeholders. We extracted the stakeholders such as the developer (CSI), the software owner (HHT), the purchasers (consulting vendors), and the potential operators (consulting vendors, nursing home vendors, staff in nursing home, and occupants in nursing home). Then, we drew the stakeholders' end objectives. Finally, after we did some analyses, we revealed the stakeholders' requirements for the visualizer. The main requirements of the visualizer are given in Table 1. We listed them in the order of implementation priority

3.2 Visualization Method

First, we broke down the requirements above, furtherly, and found out some problems as follows.

(1) When fulfilling the requirements No. 1~ No. 3, we found that it is difficult to enable users to access data with multi-dimensions for interactive analysis. For example, for the first issue "grasp of work situation", we may want to see the information about staying time, which is one of the visualization elements, from different viewpoints such as different days of the week, different occupations, different places, and so on. Regarding that, many visualization screens need to be shown. As a result, it takes users a lot of time to find screens they really need.

Table 1 Requirements of Visualizer

No.	Requirements	Reasons	Related stakeholders
1	Data can be visualized with minimum granularity.	Users can view visualization results with any granularity.	Manager in HHT, Consulting vendor
2	Data can be visualized in different dimensions, hierarchies, categories, and levels.	Users can view visualization results from many viewpoints.	Manager in HHT, Consulting vendor
3	Interactive operations are available.	Users can perform analysis according to their own will.	Manager in HHT, Managers in nursing home vendors Consulting vendor
4	All visualization elements related to hypotheses are accomplished.	User can use tool to analyze all issues in hypotheses.	Manager in HHT, Managers in nursing home vendors
5	Result reports can be output automatically.	It is convenient for users without statistical knowledge.	Managers in nursing home vendors Staff in nursing home, Occupants in nursing home and their families

Table 2 Basic Visualization Elements

Visualization elements	Descriptions	Visualization images
Staying location	Visualize staying location, which is where the staff member stay, in multi-dimensions and multi-levels	
Staying time	Visualize staying time, which is how long the staff member stay there, in multi-dimensions and multi-levels	
Staying person	Visualize staying person, which is the person who stays there, in multi-dimensions and multi-levels	
Communication network	Visualize communication situation in multi-dimensions and multi-levels	
Bubble chart to see lack of balance	Visualize lack of balance in shifts, staying time, and communication in multi-dimensions and multi-levels	

(2) When fulfilling the requirement No. 4, we created all the sample images for all the hypotheses. Through discussions, we found that there were some redundant sample images, so it was necessary to narrow them down to some basic visualization elements.

(3) When fulfilling the requirement No. 5, we realized it is convenient if the visualizer can output the reports corresponding to the hypotheses with multi-dimensions and multi-levels.

Then, to meet all the requirements by solving the problems given above, we developed the nursing home visualizer with the following features.

(1) We designed an interactive dialog. In view of the fact that all the visualization elements use almost all the same multi-dimension parameters, shown in Figure 2, an interactive dialog called "data filter" that included all the multi-dimension parameters was designed. By using the interactive dialog, you can select any dimension combination at any level you want. We divided the contents

of the interactive dialog into Level 1, Level2, Level 3 and Level 4. For example, contents of Level 1 include "when", "where", and "who". Contents of Level 2 include floor numbers, and other contents. Contents of Level 3 include room numbers, and other contents. Contents of Level 4 include places names in rooms such as toilet and bed, and other contents.
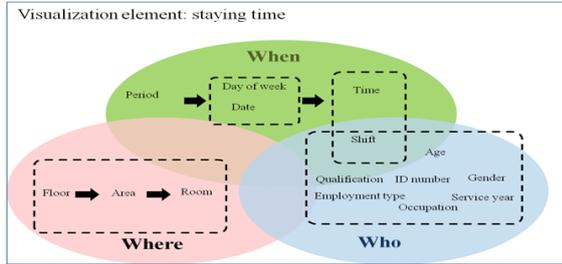

Figure 2 Sample of Multi-dimension Parameters

(2) We narrowed down the number of visualization screens to five visualization types, which can be called basic visualization elements. The basic visualization elements are shown in Table 2. Additionally, new visualization elements that have common multi-dimension parameters can easily be added later, so it takes less time to meet new demands from users.

(3) We designed an automatic report function with interactive dialog. As a result, by using the interactive dialog and the basic visualization elements, we can easily get visualization reports about almost all the hypothesis. Additionally, monthly reports for staff members and occupants can be also output. The report categories are show in Table 4.

Table 3 Report Categories

Report categories	Contents	Sample images of reports
Work situation of nursing home	Dashboard with work area and visit situation, Dashboard with work time and work location, Dashboard with location in which the staff members spend more time and its visit situation Dashboard with rest situation, Dashboard with communication situation, Dashboard with overtime situation, Dashboard with overtime reason, Dashboard with overtime differences for staff with different qualifications, Dashboard with staying time, and so on.	Dashboard with rest situation
Monthly report for staff member	Dashboard with staying location and shift situation, Dashboard with moving speed and overtime situation	One day of monthly report for a staff member
Monthly report for occupants	Dashboard with care situation, visit situation, and vital data	Monthly report for occupant in room No. 201

4. Proof of Concept

To verify the solution concept we proposed, we carried out a proof of concept (PoC) in a paid nursing home along with Hitachi High-technologies Corporation (HHT). In this chapter, we will introduce the process of the PoC.

4.1 Hypothesis Generation

To set up hypotheses, it is necessary to grasp nursing home situation. Therefore, first, we request consulting investigation company to implement a questionnaire survey for nursing homes. We will not introduce the format of the questionnaire here. After the questionnaire survey, we understood the issues the nursing homes are facing and their order priority. Then, we went to three paid nursing homes and did some hearings and ethnographic investigations. Based on the results of the questionnaire survey and ethnographic investigation, we made 19 hypotheses, which include not only issues related to work efficiency improvement but also other potential issues such as improvement in staff motivation, consumer satisfaction, human resource development, and so on. After discussed with HHT and the nursing home in the PoC, we listed the hypotheses in the order of priority. In the hypotheses, the visualization methods and data for visualization to discover problems are considered, corresponding to the issues. For example, for the issue "lack of grasping work situation in detail", we can visualize how long

staff members with different IDs, different job titles, or different duty shifts stay in each place, in which behavior data of staff members are used. We will not introduce all the hypotheses in this paper.

4.2 Data collection

Based on the hypotheses, we considered the data we need to collect to visualize issues in nursing homes. Four categories of data were supposed to be used, which are shown in Table 4.

Table 4 Data Supposed to Be Used in the Visualization

No.	Categories	Acquisition means	Data items
a	Behavior data of staff members	BM sensor system	Location data
			Acceleration data
			Communication data (face-to-face time)
b	Management data	Acquire from the nursing home directly	Duty roster
			Case record
			Check sheet of daily service
			Care plan
			Employee information such as qualification, age, and so on
c	Behavior data of occupants *	-	Location data
			Acceleration data
			Communication data (face-to-face time)
d	Vital data	Acquire from the nursing home directly	Vital data of nursing home occupants

(*Behavior data of occupants was not collected in the PoC because of the disagreement of occupants.)

We collected human behavior data by a business microscope (BM) sensing system developed by HHT. The BM sensing system is mainly made up of nameplate sensors and infrared ray beacons. Through the BM sensor system, we can find out where staff members are, how long they stay there, who they meet, and how their activity amount changes. Other kinds of data, such as management data and vital data, can be acquired from the nursing home.

We set up the BM sensor system in the nursing home based on the result of ethnographic investigation and the trial in our own team. In the nursing home, we set nameplate sensors for 24 staff members and infrared beacons in 149 places, such as rest rooms, the service station, the dining room, and so on.

After setting the BM sensor system in the nursing home, to verify the validation of data collection, we carried out an ethnographic investigation and compared the ethnographic results with the measurement results of the sensor system. For the ethnographic investigation, we monitored the behavior of two staff members per minute for about 4 hours. Regarding the object people, one is the leader of the helper, and the other is a normal helper. For the comparison with the measurement results, we compared the results of the situations with complement and without complement. The complement content includes filling a two-minute data gap and complements the other data through identical detection of nameplate and beacon. Complement through identical detection of beacon means if two or more nameplates are detected by one beacon, although the nameplates may not detect each other, we can say that staff with those nameplates are performing face-to-face interaction.

The verification results of data collection validation are shown in Table 5. According to the results, for the situation without complement, the precisions of both the location data and communication data are around 80%, so we can conclude that data collection is valid.

Finally, data collection was carried out from Feb. 27, 2015 to Mar.22, 2015. Behavior data of 24 staff members was collected by the BM sensor system.

Table 5 Verification Results of Data Collection Validation

		Situations with complement			Situations without complement		
		Leader of helper	Helper	Average	Leader of helper	Helper	Average
Location data	Precision	69.8%	56.3%	63.05%	86.3%	88.4%	**87.35%**
	Recall	87.6%	82.5%	85.05%	67.8%	79.2%	73.50%
	F-value	77.7%	66.9%	72.30%	75.9%	83.5%	79.70%
Communication data	Precision	37.1%	75.0%	56.05%	58.3%	100.0%	**79.15%**
	Recall	72.2%	85.3%	78.75%	50.0%	26.8%	38.40%
	F-value	49.1%	79.8%	64.45%	53.8%	42.3%	48.05%

4.3 Hypothesis verification

To verify and specify the hypotheses made above, we analyzed the graphs generated by the nursing home visualizer.

4.3.1 Analysis Process

In this section, we will introduce how to perform analysis using the nursing home visualizer. We analyzed the issues listed up in the hypotheses using the visualizer. We will introduce some examples (issues such as work efficiency difference and construction of workplace with friendly atmosphere) to show the analysis process.
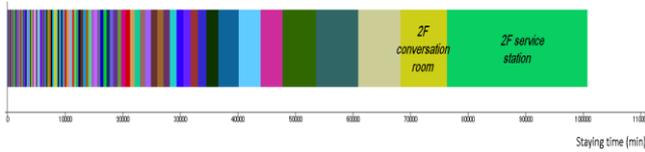
To analyze the work efficiency difference, we visualized the amount of time spent in a location and the places in which it takes the staff more time.

First, we use the "staying time" visualization element (shown in Table 2) to see the staying time in every place. As mentioned before, the staying time can be viewed on any location level from a floor (LV1) to a specific location in rooms (LV4). We found that a lot of time is spent in the 2F service station, as shown in Figure 3.

Figure 3 Staying Time

Then, in combination with the "staying location" visualization element, we discussed the places visited information. For example, we compared the visit frequency information for the 2F service station and 2F conversation room. We can see that the 2F service station's visit frequency is higher, as shown in Figure 4. We also compared the information of visit period for the 2F service station and 2F conversation room, as shown in Figure 5. Finally, we drew the conclusion that the record work in the service station consumes a lot of time.
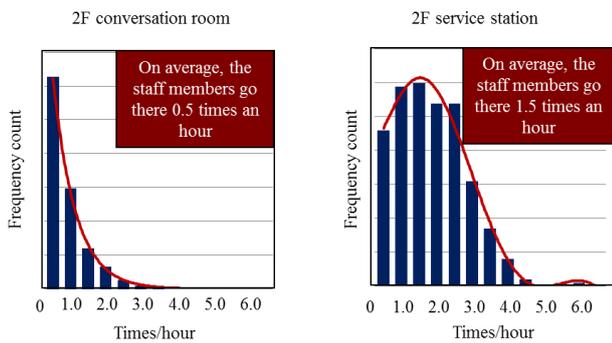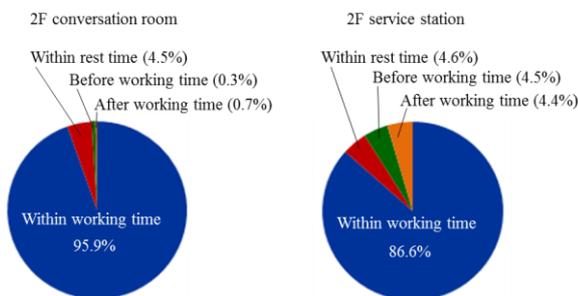

Figure 4 Distribution of Visit Frequency

Figure 5 Situation of Visit Period

For construction of a workplace with a friendly atmosphere, we visualized the communication situation of staff.
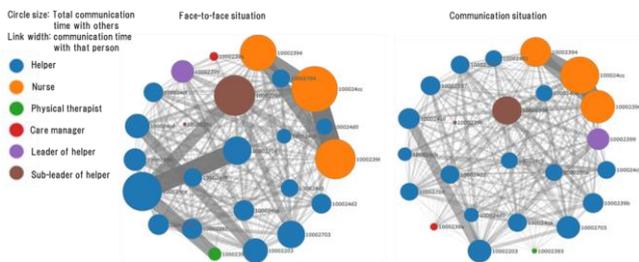

Figure 6 Communication Situation in Whole PoC Period

First, we compared the face-to-face situation, which means silent time is also considered, and the communication situation, which means only talking time is considered. The results are shown in Figure 6. We can see that although they are face-to-face sometimes, they do not talk to each other in many situations. Then, we analyzed the communication situation in other situations. We will not give out all the visualization results of other situations in this paper. For example, for

communication situation in the rest time, at lunchtime (11:15-13:30), helpers are talking to each other in the 1F conversation room while nurses, the physical therapist, and the care manager are in other places. Communication among different occupations is very rare in the rest time. Moreover, we analyzed the communication situation in the meeting time. We can see that nurses talk most in the meeting time or another period. Finally, we drew the conclusion that communication among the staff members is insufficient especially between different occupations.

4.3.2 Verification Result

Through the above analysis, all the reports shown in Table 3, such as the work situation report, the staff member monthly report, and the occupant monthly report, can be automatically output by the nursing home visualizer.

According to the priority order of the 19 hypotheses, we focused on No. 1~No. 8 this time. We also verified other hypotheses besides No. 1~ No.8 if we can verify them by the nursing home visualizer. As a result, we verified 12 of 19 hypotheses and discovered eight places that can be improved in the nursing care work as follows.

(1) The record work in the service station consumes a lot of time. In the period of data collection (24 days), about 470 hours were consumed in the "service station", which means it consumes 20 hours per day.

(2) The personnel arrangement work like creating the work shift timetable is difficult and consumes a lot of time, which led to 10 hours' overtime.

(3) The communication among the staff members is insufficient especially between different occupations. The difference in communication amount among different occupations is up to 3 times.

(4) The staying time of the occupant's room is different among staff members. In some situations, the difference is up to 10 times.

(5) The staff members who are in charge of a certain floor usually need to work in other floors where they are not in charge. For example, for the 2F early shift, 20% of the work time is consumed in the 3F where they are not in charge.

(6) In most work areas, the work time of a level 2 helper is longer than that of a certified care worker. For example, the level two helper's work time in the 3F dining room is 6 hours longer.

(7) Unpaid overtime happens often in the nursing care industry. Seventy five percent of the staff members had unpaid overtime in the PoC period, and the average unpaid overtime is 10.2 minutes.

(8) The staff members do not comply with the rest rules very well especially in the night shift. 83.3% of staff members did not take rest according to the rules, on average 21.2 minutes less than the rest time in the rules.

4.4 Improvement Measures

We proposed some measures to improve the nursing care work. We will introduce two of them in this paper.

For the first place that can be improved mentioned in section 4.3.2, one solution is introduction of devices, such as smartphones and iPads, for the record work. It is predicted that about 50% of work time can be saved due to this solution. In future, it will be possible to develop an automatic record system, which can save about 90% of work time in the service station.

For the second place that can be improved mentioned in section 4.3.2, one solution is introduction of technologies or tools to create the optimal work shift automatically. Due to the technology, 10 hours' work time could be saved every month, which means about 120 hours' work time could be saved a year.

Although the introduction of improvement measures is still being discussed, it is predicted that the total work time will decrease by 14.6% if they are introduced.

As mentioned above, we have discovered eight palaces that can be improved in nursing care work. To do the improvements, many solutions and measures will be proposed and discussed. In view of the fact that trying all the proposed measures would consume a lot of time, it is difficult to see the effects of measures quickly. Therefore, for the next step, we will develop a nursing home simulator to establish a plan for improvement in work efficiency. Using the simulator, the reports of Table 3 can be output automatically before and after introducing measures. In addition, we can display other information such as ROI (Return On Investment) numbers in the nursing home simulator. By the nursing home simulator, we can acquire the optimum combination of measures and provide them to the nursing home.

5. Discussion of Results

The results of the PoC are shown in Table 6. Although it is predicted that the total work time will decrease by 14.6% through the measures we proposed, it is not enough if nursing homes want to achieve not only benefit but also higher consumer satisfaction. It is necessary to develop other solutions besides improvement in work efficiency in nursing homes.

Table 6 Results of the PoC

Steps of Solution	Outputs of PoC	Result Descriptions
Set up hypotheses	19 hypotheses	Although we set up 19 hypotheses, it is necessary to further verify the effectiveness of general methods (questionnaire survey and ethnographic investigation) in other PoCs and perfect the guideline for them.
Collect behavior data	Data collection with about 80% precision	In view of that we collected three kinds of behavior data (location data, acceleration data, and communication data) with about 80% precision, the validation of BM sensor system as a human sensor system and the effectiveness of sensor system setting method has been verified
Verify and specify hypotheses	Eight concrete problems	Using the nursing home visualizer we developed, we verified 12 of 19 hypotheses and discovered eight places that can be improved in the nursing care work. We can conclude that the effectiveness of nursing home visualizer has been verified.
Establish improvement plan	Two measures for work efficiency improvement	Although the nursing home simulator for analyzing the return on investment (ROI) of the improvement plan has still not been developed, we also proposed two measures that can improve the work efficiency based on visualization results in Step 3. It is predicted that the total work time will decrease by 14.6% through the measures. In the future, we will develop the nursing home simulator to enforce the establishment of improvement plans.

6. Conclusions

In this research, we established a concept for the solution to improve work efficiency in nursing homes. The solution is made up of four steps. A PoC was carried out to verify the solution concept. It is predicted that the total work time will decrease by 14.6% due to the improvement points discovered and measures proposed in the PoC. Therefore, we obtained a good prospect for the solution concept. It will contribute to the nursing care business in future. We are just starting up the research about nursing care businesses, and, we will continue to research other issues related to nursing care businesses, in future.

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