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Research paper

Research on Space Systemization and Reduction of Examination Time of Medical Checkup Centers Applying the Agent -based Model

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Abstract

Modern medicine is changing from centering on treatment to prevention and from patients to the general public, and medical checkup centers, which until recently were merely attachments to the hospitals, are becoming increasingly significant independent medical facilities. Since medical facilities can provide services in more adverse conditions than other facilities, the waiting times and cognitive spatial environment are more crucial than in any other facility. However, because extremely purpose-oriented medical facilities have become very complex when considering users' behavioral factors, analysis with existing space theory has its limits. Hence, discrete-event simulation, a complex network analysis theory, was applied to spatial analysis to check for possibilities for efficiency improvement. The study was carried out by getting the space's structural characteristics using space syntax, setting up the standard checkup program and the sample space, programming in the assessment factors such as the number of people on the waitlist (maximum and average) and both the survival duration and distribution of agents into the pedestrian-based discrete-event simulation analysis tool, and using it to determine the maximum capacity of users and related problems.
On the premise that the costs are kept to a minimum, corrective measures were changed, the redistribution of some rooms' purposes and services were prepared, and the new plan's improved efficiency compared to that of its predecessor has been proven through simulations and analyses. According to the simulations, the walking distance was shortened and the path network's structure was simplified, which led to enhanced structural cognition of the space and, thus, reduced the average checkup time by 46 minutes and the maximum time required for 50 checkups by 52 minutes, resulting in increased patient occupancy by 10–20 persons with little effort and cost. Even though the results of this research were from relatively small checkup centers, it proves that complex network analysis applying discrete-event simulation to a space can be effectively utilized as an architectural tool for structurally designing medical facilities, including checkup centers. Applying it at an early blueprinting stage as a preliminary simulation tool maximizes its effectiveness and is expected to be compatible with large-scale, complex facilities.

Keywords: *Pedestrian simulation, Agent-based model, Health examination center, Space syntax. Discrete-event system specification*

1. Introduction

1.1. The goal and necessity of the research

As both the elderly population and the general public's interest in health increases worldwide, the demand for medical services will inevitably rise.
However, the increase in the number of medical services has surpassed the demand, intensifying competition in the market; gaining a competitive advantage requires improvement to either the level of quality or the level of service.
Prospective studies have shown that a hospital's service quality is affected by various aspects such as technology, price, service, and accessibility, but quality improvement is often difficult due to problems such as the cost of production and limited space.
A checkup center, which is one of the medical services a hospital provides, has a consistent structure that runs designated checkup items based on a constant procedure, in contrast to other hospital functions such as the out-patient department. In addition, the checkup fee is to some extent universalized and influenced very little by technology, so the centers are greatly affected by the environmental service quality.
Hence, this research has tried to approach the quality improvement of checkup centers from the relationship between the spatial structure and checkup services. Discrete-event simulation analysis was carried out based on agent-based model theory to seek a way to enhance the quality of checkup services while keeping costs and facility supplementation to a minimum.

1.2. The method and range of the research

This study builds on "A Study on the Optimization of the Number of Health Examination Center using Agent Based Modeling [1]". The precedent research was intended to assess the feasibility of the optimization through developing indicators and preliminary simulations

prior to the execution of this research. In this study, the content of research is made more concrete through the systematization of the spatial structure to improve the spatial cognition, the homogeneous utilization of public space in parallel with a concrete analysis of space syntax, the suggestion of alternatives to shorten the screening time by adjusting the number of services and the waiting area, and a comprehensive analysis by applying various variables. In addition, the confidence level of the result has been increased through 10 repetitive simulations, as opposed to the precedent study, which applied a single simulation during an experimental stage using indicators.
The research was executed as follows:

1. Establish a standard checkup procedure and required checkup items for an efficient and patient-friendly service.
2. Set up the sample space and determine its structural characteristics.
3. Propose an assessment index for analysis and create a simulation analysis tool that can draw results from analysis.
4. Determine where the path flows and stagnates by creating simulations in the sample space and finding problems.
5. Suggest solutions to address the problems such as rearranging rooms and adjusting services.
6. Calculate the improvement factor quantitatively by simulating it in the same manner.

A specific emergent phenomenon occurs in a simulation when interpreting complex systems, but result values contain errors in every simulation, even in the same model; therefore, working out the generalized mean value through repeated simulations increases the credibility.
This research carries out the preliminary simulation to calculate the maximum occupancy once, and the main simulation for verification was repeated ten times to yield collective data

2. Theoretical background

2.1. Increase in the supply and demand of checkup services

Modern medicine is moving from treatment to prevention and from patients to the general public. Thus, checkup centers used to be mere auxiliary aspects of hospitals are increasing in importance in terms of individual functions, leading to intensified competition due to excess supply, which is exacerbated by the national healthcare policy.
Excessive competition in the market may make a hospital face great financial danger, if it does not actively adapt to external and internal changes in its environment. The best way to prevent this is to prioritize customer (patient) satisfaction. The medical process, which is one of the most crucial factors that affect customer satisfaction, is comprised of disease treatment, which is hospitals' main purpose, and the whole process the patient goes through to receive treatment. [2]
Although various aspects of customer satisfaction can be evaluated, the most common ones include convenience, quality, and price. [3]
Checkup centers are more affected by the spatial environment, in which the patients can get examinations in a comfortable environment, than by technology, which sets them apart from treatment-oriented facilities. Reducing consultation and treatment times is recognized as an especially important factor among medical processes. [4] Since patients wait for treatment that can negatively affect their mental state compared to watching a movie or having a delicious meal, which would have positive psychological effects, waiting time can greatly influence customer satisfaction. [5]
Although hospitals are making various efforts to develop their competitive edge, most are limited to cost reduction, productivity, and professional medical services, and the hospitals' customer service consideration remains low. [6] However, even though hospitals are aware that reducing wait times is crucial, adding facilities or recruiting physicians and nurses are difficult due to the hospitals' limited resources. Moreover, it is important to analyze, before actually executing, how large-an-increase in human resources and facilities would bring an optimal outcome at a low cost. [7]
Thus, this research attempted to find a way for patients to feel more comfortable by reducing the wait time, one of customers' biggest complaints, with minimal effort and cost.

2.2. Space theory

Space theories emerged in the late 70's to interpret space from a structural perspective. Among these is the space syntax theory, as suggested by B. Hillier, which is a value-neutral theory that reconstitutes space as a unit and explains the hierarchical aspect of space through only relationships among unit spaces.
Space syntax has been recognized as a well-verified theory through many previous studies and has been applied to much research related to medical facilities. Space syntax is used to apply space theories to evaluate space efficiency, or how rational space is, but analyses have shown limitations for the following reasons.
First, space syntax is not bound by physical distance in a space, but rather emphasizes spatial cognition based on the change of direction, or simply the psychological distance. Thus, it is unaffected by physical factors such as the distance travelled or the service time.
Second, space syntax assumes infinite free walking, thereby being unable to decide on a destination or procedure required for analysis. There has been a case in which visual graph analysis, the opposite concept to space syntax, was introduced, but it is hardly related to purposeful walking in principle.
Third, as it is a probabilistic theory based on networks, it is difficult to assign additional variables such as excess demand of the service, the wait resulting from excess demand, and users' personalities and characteristics.
For the above reasons, analyzing purpose-oriented spaces such as checkup centers is often met with limitations and preparing a practical alternative has many problems.
This research attempts to find problems and their solutions for checkup centers using pedestrian-based discrete-event simulation, which shares its fundamentals with space syntax, an agent-based model.

2.3. Agent-based model and discrete-event simulation

Space has a complex morphological structure and is thus difficult to analyze. In addition, if the behavior of users in a space is taken into account from a societal perspective, the number of elements that are mutually related increase astronomically and the relationships become extremely complicated.

Similarly, the extremely convoluted societal structure of a space can be seen as a type of complex phenomenon; thus, this research also ran simulations and analyses to perceive the space as a complex system.

Space syntax mathematically calculates relationships by topologically drawing spaces based on networks, whereas the agent-based model simulates and analyzes based on the relationships between the various attributes of numerous objects.

The agent-based model has been applied in various fields including the economy, services, production, logistics, distribution, business, military, transportation, and aerospace, and is currently being tested in urban architecture. This model requires analyzing the relationships between numerous objects and variables, thus relying on computers for calculations, which were greatly enhanced by mathematical algorithms for parallel processing and distributed networks.

These computer-run analysis simulations are divided into system dynamics, discrete-event simulations, actor models, etc., and the most well-known simulation development tools include Arena, NetLogo, and AnyLogic.

AnyLogic, which is used in this research, is an agent-based model simulation development tool released in 2000 that supports various complex network analysis theories and useful information technologies such as the object-oriented method of approach, standard Unified Modeling Language (UML) factors, and a modern Graphical User Interface (GUI). Users can also extend simulation models through Java code.

3. Simulation configuration

3.1. Required space and checkup procedure settings

Medical checkup programs vary according to each center's operational policies, which means that many centers abandon systemization to accommodate as many patients as possible. However, unsystematic checkup procedures do not take convenience into consideration and may make checkup processes chaotic; therefore, the standardization and systemization of checkup procedures are absolutely necessary.

This research selected the basic checkup designated by the Health Insurance Corporation, which is the most widely used checkup, as the standard checkup program and items were set according to the national standards suggested by the Ministry of Health and Welfare.

Checkup programs were set differently for men and women as stated by law, and the course and required space for women's checkups were a little different, thereby dividing the gender groups to acquire more accurate data.

The checkup procedures were set according to the standard program as shown in Table 1, which takes every situation and practice of currently operating centers into account, as well as the research done by Jee Hee Jung [9], Seung Woo Han [10] and Seung Eon Song [11] based on the order designated by the Association of Medical Checkup Management of Korea [8]

Table 1: Standard checkup program and procedures

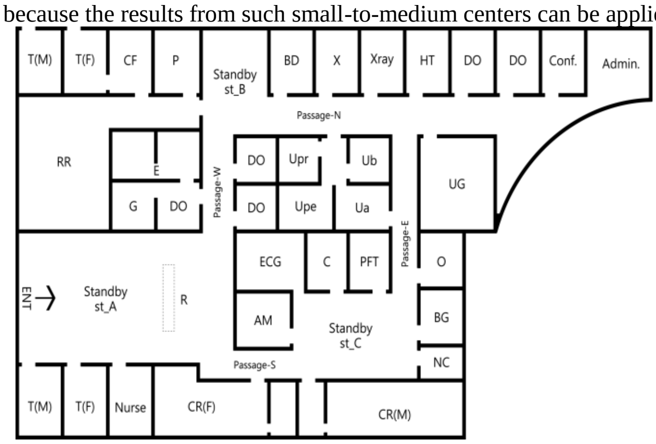
Male	R → CR → MEI → AM → BG → CU → O → HT → D → ECG → PFT → Xray → Ua → UG → En → RR → NC → CR → Exit
Female	R → CR → MEI → AM → BG → CU → O → HT → D → ECG → PFT → X → Upe → UG → En → G → RR → NC → CR → Exit
LEGEND : AM : Anthropometric measurement, R : Reception BG : Blood-gathering, CR : Changing room, MEI : Medical examination by interview, CU : Collection of urine O : Ophthalmology, HT : Hearing Test UG : Upper gastrointestinography, Xray : Xeromammography BD : Bone Density, U : Ultrasonography ECG : Electrocardiogram PFT : Pulmonary function test, En : Endoscope, RR : Recovery room, NC : Nutrition consultation, G : Gynecology, CF : Colonofiberscope, Ub : Breast ultrasonic, Ua : Abdomen ultrasonic Upe : pelvic ultrasonic Upr : prostate ultrasonic, T(M) : Men's Toilet, F(M) : Ladies' Room	

3.2. Sample space settings

The checkup center chosen as the sample facility was the J Hospital Checkup Center in Gyeonggi-do, a center that is only for medical checkups and has no other function. (Fig. 1)

This facility has clearly separated zones for its checkup center, and all basic checkups—with the exception of rare optional checkups—can be taken on a single floor. Moreover, it is relatively small, which makes it easier to spot problems.

It was chosen as the sample space because the results from such small-to-medium centers can be applied to larger centers later.



LEGEND:
DO : Doctor's Office, st_#; Stand by #
C : Counseling center, P : Preparation room,
* The remaining room name (code) is identical to the legend in Table 1 above.

Fig. 1: Floor plan of the subject checkup center

3.3 Structural characteristics of space (space syntax)

The checkup center selected as the sample space has total area 917.99 m2, of which 323.22 m2 or 32.9% is for public use. The bathroom was used for urine collection, and thus was not included in the area for public use.

The total floor space measures 45 x 26 meters, and the analysis program was set up by visualizing and arranging the wall lines in 200-mm intervals on CAD, using the image as a background to define wall objects and add both agents and event networks.

There are screening rooms that can run all checkup items required by the Health Insurance Corporation, doctors' offices, nursing rooms, and the administrative office, along with examination rooms for colonoscopy, bone density measurement, prostate ultrasonography, and pelvic ultrasonography. No dental clinic was installed; therefore, this was not included in the checkup process.

The structural characteristic of the space is a typical ring-shaped structure in which the hallway is split into two at the entrance and joined again at the opposite side.

According to the structural analysis using the space syntax, the first spatial center was the west hallway and the next was waiting room-B. In contrast, the north hallway had the highest local integration followed by the south hallway, and the visitors can perceive the space through these hallways. Thus, waiting room-C, which is connected to these hallways, plays a significant role, and moving waiting room-B eastwards should be considered.

Connectivity (Fig. 2) and control values (Fig. 3) came out in similar ways, and both indexes were highest at the north hallway, which had the highest local integration. (Figs. 4,5)

This is because it is where many rooms were connected in parallel. The Pearson product-moment correlation coefficient between the local integration of depth three and global integration that shows intelligibility was 0.921, which was relatively high, showing that the space's structural arrangement was simple. (Table 2, Fig. 6) Moreover, AnyLogic was selected as the analysis tool because the intuitive analysis of pedestrian model is easier than other programs.

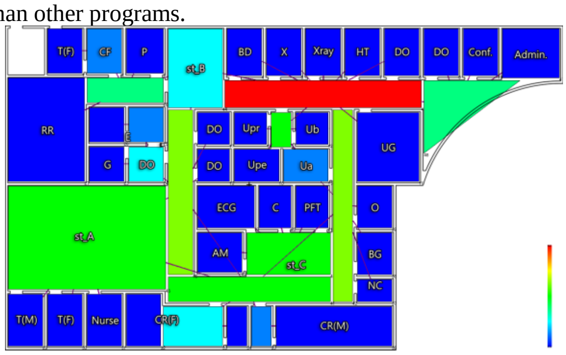


Fig. 2: Connectivity

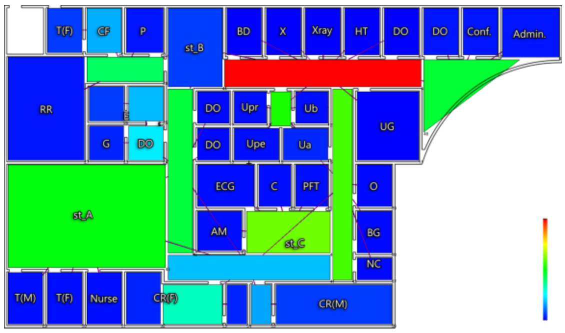


Fig. 3: Control Value

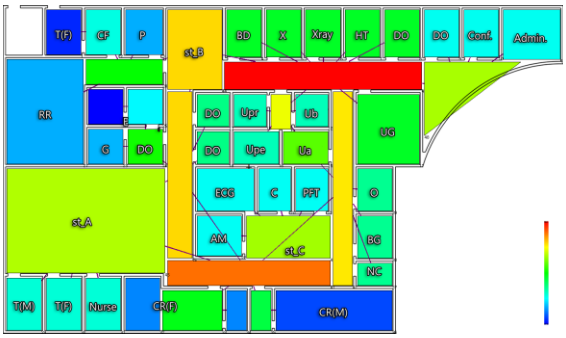


Fig. 4: Global Integration

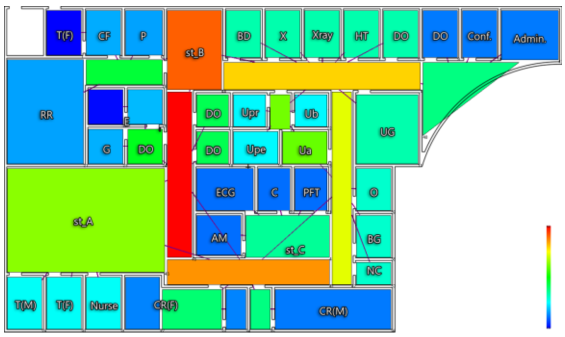


Fig. 5: Local Integration

Table 2: The space syntax analysis results (calculated by MS Excel)

ID	Conn	CV	Int*	Int r3	Intelligibility
average	2.042	1.000	1.046	1.230	0.921
maximum	1.000	0.111	0.684	0.422	
minimum	9.000	6.783	1.781	2.445	

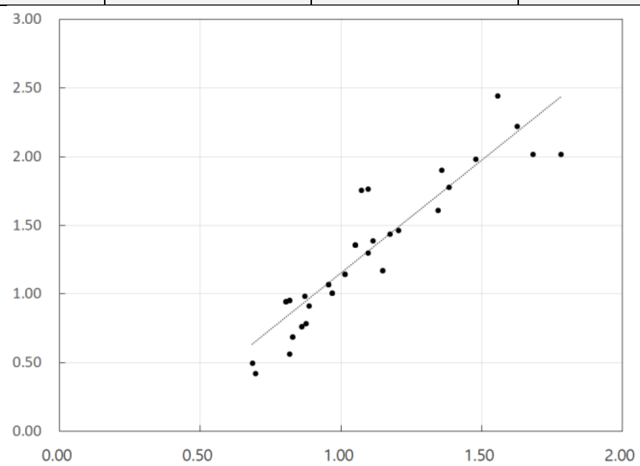


Fig. 6: Space intelligibility

3.4. Workflow composition

According to the National Health Insurance Corporation's 2015 Annual Checkup Statistics Report, 53.184% of checkup recipients were male, 54.128% being the actual number of recipients. Hence, the agent ratio in the simulation was set to 54.128% male and 45.872% female.

Although agent activity may vary according to different situations, the interval in which the recipients applied for checkups was set to 1–2 minutes, and the agents appearing in the simulation space, therefore, depended on their maximum value (maximum recipient occupancy).

The recipients choose between endoscopy and upper gastrointestinography (UGI), for which actual statistics do not exist; thus, one out of five recipients (20%) was set to receive a UGI and the remainder received an endoscopy as deduced from information collected from the Internet.

The recovery room is only in the path for those who received an endoscopy under conscious sedation. The ratio, as calculated from data collected on the Internet, was set to one in four (25%).

Harmony with the settings of actual checkup centers was achieved by placing 30 lockers in the dressing room and 20 beds in the recovery room, and the number of recipients who simultaneously received each checkup was set as follows: three for ophthalmologic examination and blood sampling, two for gastroscopy, and two for anthropometry (body measurements).

The minimum and maximum numbers of services are shown in Table 3, and Fig. 7 shows the network structure of the checkup procedures in a diagram.

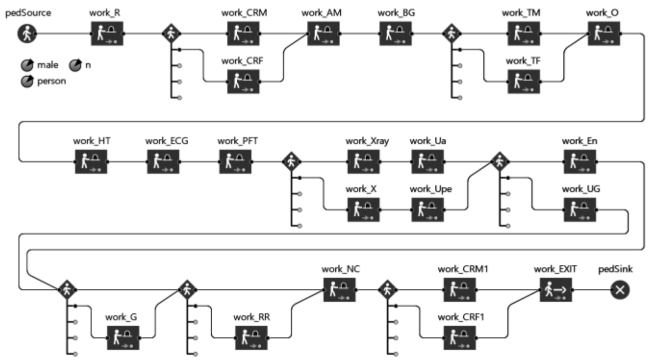


Fig. 7: Workflow chart

Table 3: Number of services and durations per examination room

Work	program	services	Description	Min	Max
Work_R	R	3	Reception	2	3
Work_CRM	CR	30	Changing Room (Male)	5	10
Work_CRF	CR	30	Changing Room (Female)	8	14
Work_AM	AM	1	Anthropometric Measurement	2	4
Work_BG	BG	3	Blood Gathering	2	3
Work_TM	CU	4	Men's Toilet	1	2
Work_TF	CU	4	Ladies' Room(Toilet)	2	3
Work_O	O	3	Ophthalmology	4	5
Work_HT	HT	3	Hearing Test	2	3
Work_ECG	ECG	1	Electrocardiogram	5	10
Work_PFT	PFT	1	Pulmonary Function Test	5	6
Work_Xray	Xray	1	Xeromammography	2	3
Work_X	X	1	Breast Xeromammography	8	15
Work_Upe	Upe	1	Pelvic Ultrasonic	5	10
Work_UG	UG	1	Upper Gastrointestinography	6	9
Work_G	G	1	Gynecology	5	10
Work_Ua	Ua	1	Abdomen Ultrasonography	3	5
Work_En	En	2	Endoscope	5	10
Work_RR	RR	1	Recovery Room	25	35
Work_NC	NC	1	Nutrition Consultation	2	3

3.5. Evaluation index settings and data measurement algorithms

An evaluation index that fits the research purpose is required to comprehend the efficiency and problems of a space and find a solution. This research uses three kinds of indexes: the number of those in the wait-list, the duration of agents (time required for each checkup) and the distribution of the durations, for which the data was calculated through simulations.

3.5.1. Number of wait-listed recipients

Each required room is assigned a wait time in accordance with the checkup being performed. People have to queue if the examination room is full, and the waiting area has to be assigned as either linear or as an area, depending on the designated space.
If the number on the wait-list increases, the waiting time increases, which leads to longer total checkup times. Hence, the number of wait-listed patients was set to the wait-listed patients for each time period and each examination room. Since the wait-list changes over time, the data table had examination rooms as the x-axis and time as the y-axis added into the database every 10 seconds and deduced the number of those wait-listed and the maximum capacity for each examination room.

3.5.2. Agent duration

In a simulation, 1–2 agents were added every minute until reaching maximum number of agents(occupancy), so that the time parameter (ped.timeAdmitted) was defined for each occurring agent; the current time was saved as the default value, and the values excluding the occurring time parameter were set, which was saved when the workflow was completed and sank at the exit as the agent duration.
Each agent is assigned an arrival number, using which the duration—the total checkup time of each agent—is recorded.
Each agent may go through different workflows with fixed probability, and the arrival and departure numbers can therefore differ.

3.5.3. Distribution of durations

The final batch of agent durations was divided into 50 intervals and these were made into a histogram with percentages per section.
The intervals of the sections always change because the maximum agent durations are reversible, but the maximum agent durations are useful when getting the overall distribution of checkup times and verifying the total checkup times by multiplying the average times for each section by the number of agents and summing them.
Each agent's duration (time()-ped.timeAdmitted) was saved to the histogram parameter (histLOS) and was connected to the histogram graph to extract data.
The discrete-event simulation that calculates the above index was set using AnyLogic 8.2.3 [12] and the index calculating program was coded. The final version of the analysis program is as shown in Fig. 8 and Fig. 9.

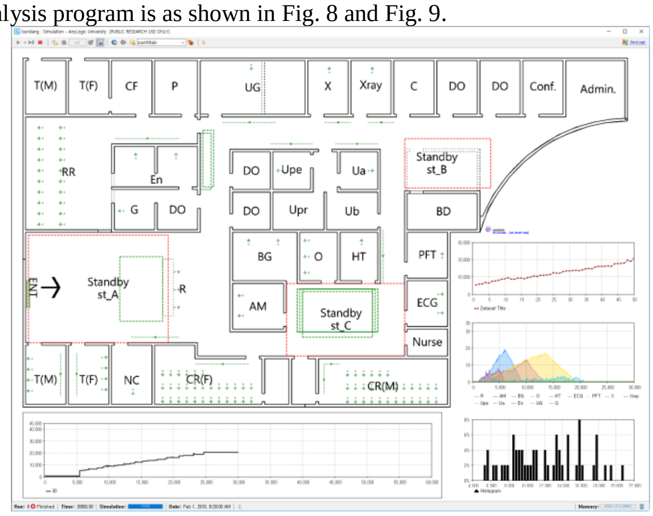


Fig. 8: Analysis program

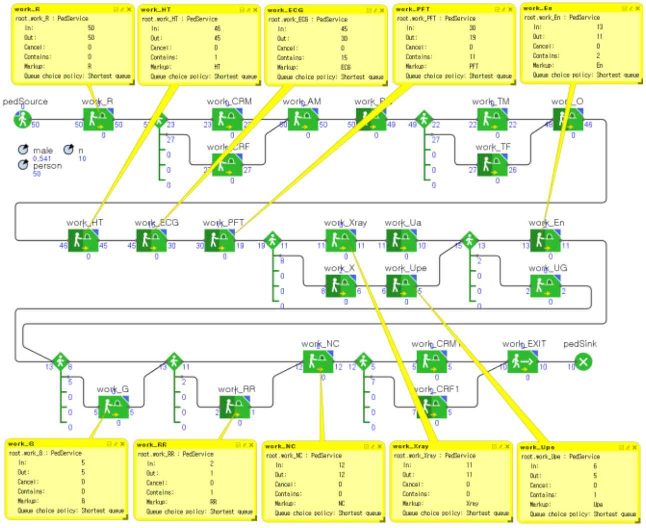


Fig. 9: PML and Parameter measuring

4. Agent-based simulation

4.1. Estimating capacity

The capacity of target checkup centers were evaluated by running preliminary simulations once per section, changing the number of agents from 10 to 100 in intervals of 10.

Thus, as shown in Fig. 10, when the capacity was 10 people, it took 2 hours, 57 minutes, and 20 seconds (10,640 seconds) for all recipients to complete checkups; 7 hours, 2 minutes, and 12 seconds (25,332 seconds) with 50 people; and 13 hours, 27 minutes, and 14 seconds with 100 people. Considering that checkups start at 8 am, completing all checkups before noon means that 30–40 people can actually receive checkups.

Checkup centers cannot hold more than that now, but the goal in the improvement plan was set at 50 people to evaluate its effectiveness.

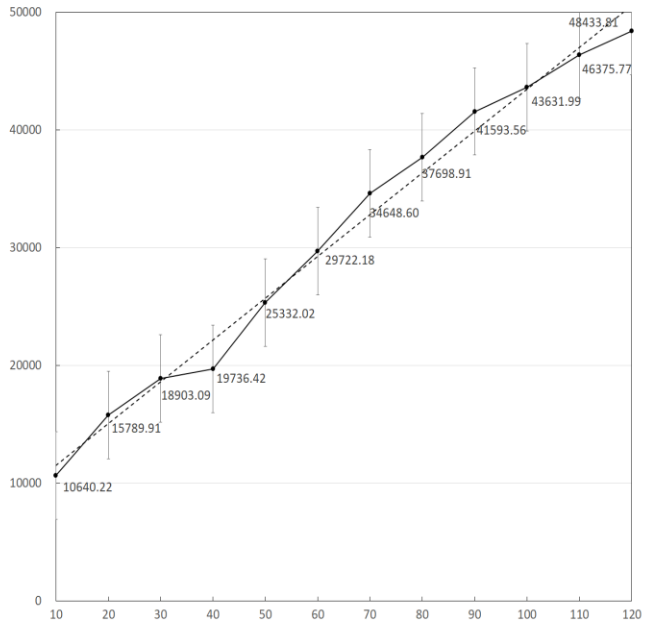


Fig. 10: Number of agents and durations

4.2. Analyzing the current state

Ten simulations were repeated to calculate more-accurate indexes.

Thus, the agent that underwent the first checkup took 1 hour, 14 minutes, and 23 seconds (4,463.81 seconds) and the agent that finished last required 7 hours, 6 minutes, and 12 seconds (25,572.42 seconds).

According to the analysis, the agent that completed the final checkup did not enter last nor took the longest because the course and time vary in accordance with gender and the type of checkup was chosen at random.

The wait-list per time graph (Fig. 15), that was made to understand reasons for long checkup times, showed that the electrocardiogram (ECG) and hearing tests (HT) had long wait-lists.

The ECG had up to 34 (average 32.8) in the wait-list at the 9,800–10,100 second interval and the HT had up to 20 (average 18.3) in the wait-list at the 6,400–6,800-second interval, proving that the waiting time that occurs here is the main reason for the increased checkup

times. This is similar to the Heatmap in Fig. 11, suggesting that pedestrian density can be increased in waiting area-C and the east side of the north hallway, which does not have a separate waiting area and can therefore become more chaotic.
Furthermore, like the “Before” image in Fig. 13, having complicated paths, which increases the walking distance, can lead to lower spatial cognition and longer walking times. Improving the service (examination) handling capacity in crowded areas and reducing the walking time by rearranging paths may resolve this problem.

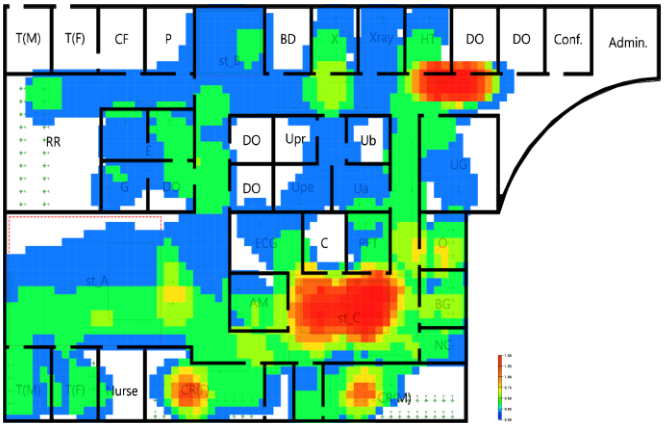


Fig. 11: Recipient density

4.3. Improvement plan settings

According to the analysis above, the time delay is related to certain areas being caught in a bottleneck.
Resolving the bottleneck problem by increasing the number of services that require large spaces or expensive medical equipment or by changing the checkup procedures has to be considered, but since this research assumes following the standard procedures, adjustments were made without increasing manpower, costs were kept minimal, and the plane form (wall section) of existing checkup centers was followed as closely as possible.
First, paths were simplified following the checkup procedures to reduce checkup times and improve spatial cognition. However, the basic objective was minimizing costs, so the room arrangement was modified as follows: the bathroom’s location, which is a facility, was left unchanged, wall layout changes were kept to a minimum, and the public area ratio was maintained.
Overlapping paths were simplified by exchanging the minimum number of spaces following the checkup sequence; the traffic in public spaces was reduced by making waiting areas shareable. In addition, spaces that needed more checkup services were given more space and unnecessary parts were reduced.
Thus, as shown in Fig. 12, the ophthalmic clinic (O) was moved to where the nutritional counseling room (C) was, the counseling office was moved to where the HT room was, the hearing test room was moved to where the PFT room was, the pulmonary function test room was moved to where the ophthalmic clinic was, and the nurses’ station and nutrition counseling room (C) traded places.
Another reason for exchanging spaces is to procure a larger area for more services.
The HT and ECG rooms, where significant traffic occurs, had their number of services increased by one, and that of the three blood sampling rooms was decreased by one, moving two people from the blood sampling rooms to the hearing test room and electrocardiogram room.

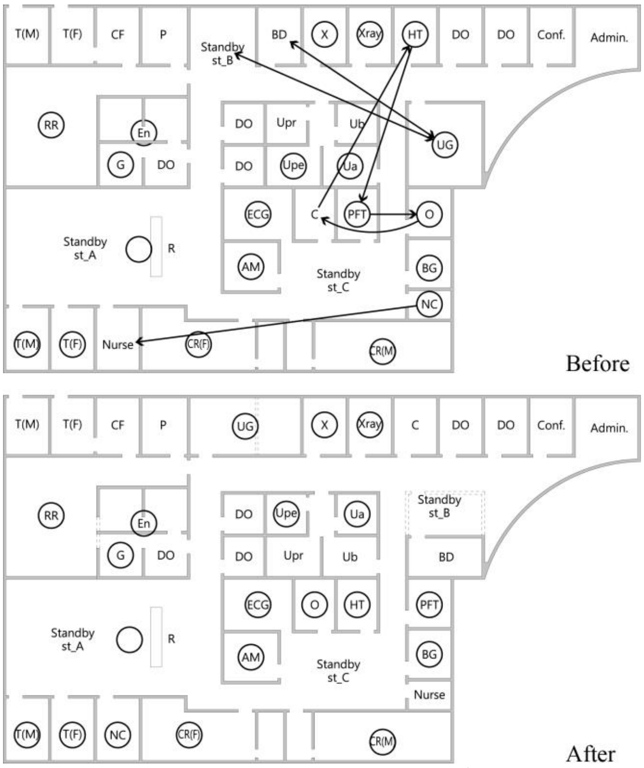


Fig. 12: Improvement plan settings and modification plan

This room exchange was approved while also taking spatial cognition into consideration, and the path structure was simplified as shown in Fig. 13(after) and its network structure, which shortened the walking distance and enhanced the spatial cognition.

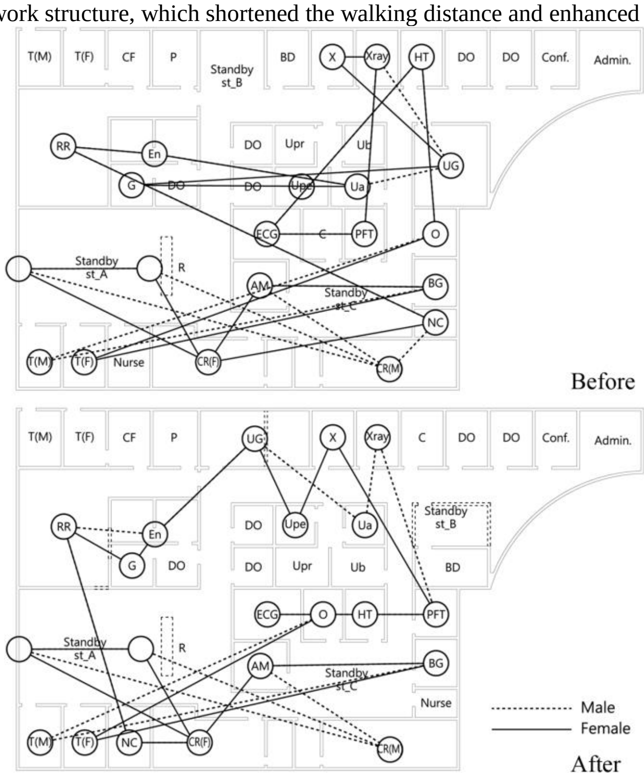


Fig. 13: Change in checkup network before and after modification

4.4. Verifying simulations and comparison with the original plan

The improvement plan (After) was run through simulations with the same indexes and procedures as those used for analyzing the original plan (Before), and the results were compared. (Fig. 14)

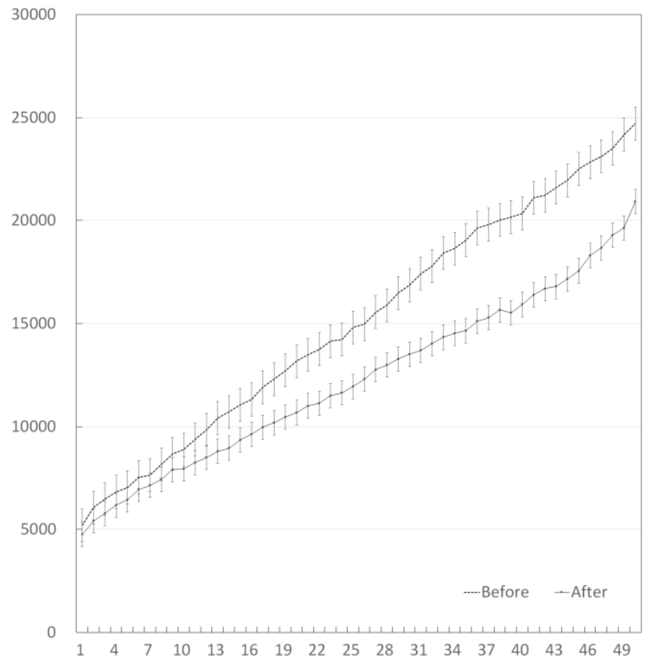


Fig. 14: End times per agent

As shown in Fig 10, the results are as follows: the average checkup time per person for a 50-person group with the original plan was 4 hours, 11 minutes, and 10 seconds (15,070.61 seconds), while that of the improved plan was 3 hours, 24 minutes, and 18 seconds (12,258.66 seconds), which is 46 minutes and 52 seconds shorter.

The longest checkup time in the original plan was 6 hours, 41 minutes, and 10 seconds (24,070.80 seconds), while that of the improved plan was 5 hours, 48 minutes, and 40 seconds (20,920.27 seconds), which is shortened by 52 minutes and 30 seconds, allowing checkups to be completed earlier and evening out the average checkup times for each recipient.

Hence, while only about 30–40 people could get checkups before noon with the original plan, this number increases to 50 people through the improved plan.

Thus, adjusting the wait-list can be seen as the most effective way to make improvements.

As shown in Table 4, the sum of the average maximum number of those wait-listed through 10 simulations was 58.1 for the original plan and 57.5 for the improved plan, which is not significantly different (98.97%). However, the average number of those wait-listed for each examination room was 1.132 for the original plan and 0.799 for the improved plan, which is a large decrease (70.58%).

This reveals that the number of those wait-listed is similar in the two cases, but the queue does not get concentrated at a particular examination room with the improved plan.

Graphing the original plan (Fig. 15) and the improved plan (Fig. 16) shows a more intuitive comparison, which demonstrates the reason for the decrease.

While the original plan was concentrated on the ECG, the improved plan was divided into blood sampling (BG), ECG, and pulmonary function test (PFT), thus reducing the peak queue from 34 (ECG) to 19 (PFT).

The decrease in waiting time results from moving the HT room, the main reason for delays, to a larger place and increasing the number of services for the relatively cheaper HT and ECG to enhance the checkup capacity and quickly absorb the queue.

The increase in required manpower did not necessitate more recruits because the two people working at the BG room, where there was no wait-list were moved to hearing test and electrocardiogram.

In short, there was an increase in the queue at the blood sampling and pulmonary function test, where people were rarely wait-listed, but the average checkup time per person and the total time required to perform checkups were notably shortened, which is a huge overall improvement.

As a side note, simulations revealed that about 1–2 people usually used the 30 beds that were installed in the recovery room (RR), and this number did not exceed three. Reducing the space and the number of beds to use the recovery space for other amenities or widening the space between beds could be considered, but this was not applied in this research.

Agent simulations can reveal facilities that are excessive or lacking, making up for this and repeating simulations can then show the effects after improvements have been made.

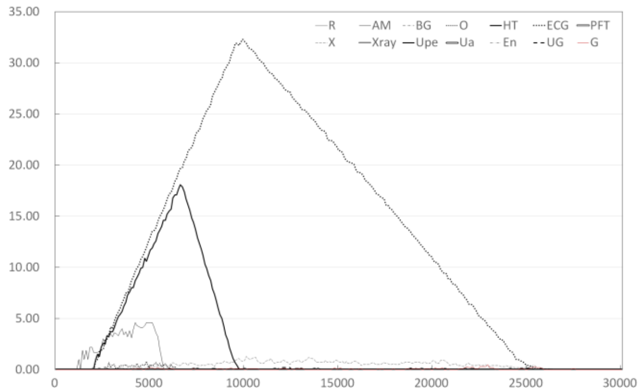


Fig. 15: Changes in queue pattern per time (before)

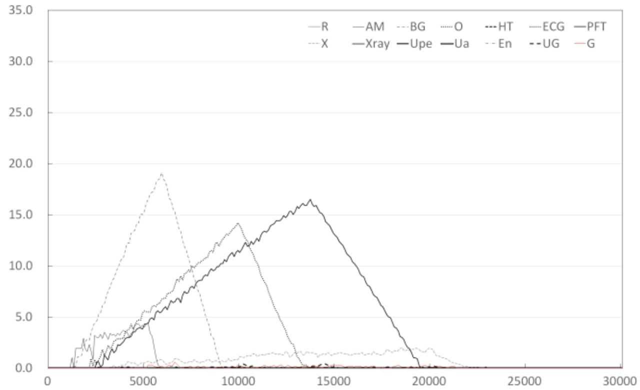


Fig. 16: Changes in queue pattern per time (after)

Table 4: Maximum and average queue per examination room

Service	Before		After	
	Maximum	Average	Maximum	Average
R	0.000	0.000	0.000	0.000
AM	4.600	0.454	4.400	0.440
BG	0.000	0.000	19.100	2.483
O	0.800	0.051	0.000	0.000
HT	18.100	2.304	0.100	0.000
ECG	32.300	12.534	14.200	2.622
PFT	0.100	0.004	16.500	4.853
X	1.300	0.427	2.000	0.666
Xray	0.000	0.000	0.000	0.000
Upe	0.000	0.000	0.000	0.000
Ua	0.100	0.000	0.000	0.000
En	0.100	0.007	0.200	0.015
UG	0.200	0.016	0.400	0.031
G	0.500	0.047	0.600	0.074
	sum=58.100	avg=1.132	sum=57.500	avg=0.799

5. Conclusion

The most important things at medical facilities like checkup centers are the rationalization of spatial cognition through systematizing paths and minimizing checkup times. Therefore, the rearrangement of examination rooms and adjustment of medical services (redistributing human resources) were suggested as an improvement plan.

This research ran agent-based simulations on checkup centers to find problems and quantitatively showed an increase in efficiency by suggesting an improvement plan that amended the arrangement of examinations rooms at minimal cost.

The results gathered from the research can be summarized as follows.

First, the main reasons for longer checkup times are excessive queues and increased walking distance. However, when there is a long wait-list, the walking time (distance travelled) is not particularly influential. Hence, reducing the walking distance plays a bigger role in closing the psychological distance to make the recipient's spatial cognition easier rather than it does in preventing queues.

Second, the best way to reduce the total checkup time is to adequately distribute traffic so that the queue is not concentrated to certain services (such as examination rooms). Therefore, the size of the spaces in proportion to the number of services should be decided after calculating the number of services through simulations.

Third, rearranging the examination rooms to fit checkup procedures allows paths to be shortened, which leads to enhanced cognition and homogenizes the density of public spaces.

If cost is no issue, aggressive measures such as rearranging partitions can further maximize the effects.

The simulation method suggested in this research is an analysis of existing checkup centers, but applying it earlier in the planning stage, matching it with the number of services, and evaluating its adequacy can increase the efficiency of the architectural space planning.

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References

[1] Kim, ST. (2018) A Study on the Optimization of the Accommodation Number at Health Examination Center using Agent Based Modeling. *International Journal of Hybrid Information Technology*, 11(1), 1–6

[2] Oh, KE, Bak, WS, Han, SS, Park, SC, & Lee, SC. (2013) Developing Innovation Index of Hospital Service using 6Sigma and SERVQUAL. *Journal of Korean Society for Quality Management*,41(4), 555–566

[3] Dyer, R. F. & Forman, E. H. (1993). An Analytic Approach to Marketing Decision, Prentice-hall International Edition

[4] Dansky, K. H, & Miles, J. (1997). Patient satisfaction with ambulatory healthcare services: waiting time and filling time. *Journal of Healthcare Management*, 42(2), 165.

[5] Park, CS, Kawg, EJ. (2009). A Case Study about Managing Waiting Time for Raising Customer's Satisfaction in the Medical Service, *Korean Journal of Hospital Management*, 14(3), 132–133

[6] Kwon, BH. (1997) A Simulation Analysis for the Minimization of Outpatient's Waiting Time at the Enrollment and Receipt Counter in a General Hospital, *Journal of Korean Society of Computer and Information*, 2(1), 98

[7] Yeo, HJ, Bak, WS, Yoo, MC, Park, SC, & Lee, SC. (2014). Evaluation of patients' queue environment on medical service using queueing theory. *Journal of the Korean Society for Quality Management*, 42(1), 71–79.

[8] Korean Associate of Health Promotion Official Homepage (2018, Feb 3). Retrieved from http://www.kahp.or.kr/cms/ doc.php?tkind=1&lkind=1&mkind=2

[9] Jung, J. H. (2011). A Study on the Space Plan of a Health Examination Center Based on Environmental Psychological Behavior (Master's Thesis), Hanyang University, South Korea

[10] Han, S. W. (2008). *A Study on the Spatial Composition & Using Circulation of Health Promotion Center in General Hospital* (Master's Thesis) Hanyang University, South Korea

[11] Song, SE & Kim, ST (2012). A Study on Traffic Line Efficiency of Health Examination Centers Based on Space Syntax : Focused on the Spatial Cognition of the Testee Taking the National Examination Program, *Journal of Institute of Healthcare Architecture*, 18(4) 53–67

[12] Anylogic Official Homepage (2018, Feb 4). Retrieved from http://www.anylogic.com