



Work pressure and burnout effects on emergency room operations: a system dynamics simulation approach

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Abstract

This study develops a simulation model that can describe the accurate working environment of emergency room by analyzing the effects of both work pressure and burnout. For this purpose, we consider burnout as a critical factor that plays a role in running an emergency room efficiently and as a cause for unexpected outcomes. As work pressure intensifies, the productivity of human resources tends to increase accordingly. However, when work schedule intensity reaches a certain level, service productivity of human resources can start decreasing due to accumulated fatigue. We consider the burnout phenomenon and demonstrate the existence of several such factors in emergency room environments through systems dynamics simulation model by comparing them with the actual emergency room data from a major hospital in South Korea. Also, we conducted trend analysis to present the behavioral characteristics of the burnout.

Keywords Emergency room · Burnout · System dynamics · Nonlinearity

1 Introduction

As the economic importance of the service industry increases, so has the effort to improve productivity in the service industry. However, these efforts have been somewhat limited to the application of manufacturing approaches to services without comprehensive consideration of the unique characteristics of services distinguished from manufacturing. There have been a number of studies on service productivity improvement (Johansson and Olhager 2004; Lee 2017; Machuca et al. 2007).

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However, the majority of these studies attempted to apply a manufacturing framework to the service industry (Johansson and Olhager 2004). Even though such efforts were useful, applications of manufacturing approaches to service ignore the unique characteristics of the service industry (Grönroos and Ojasalo 2004). Service productivity, for example, depends on human resources, whose capacities vary and have nonlinear relationships with various influential factors, while manufacturing productivity tends to depend on machines and equipment with their variability tending to be much lower (Oliva and Sterman 2001).

In recent years, service quality has attained considerable importance because there has been an increased demand for better health care services to improve life style (Lee 2017; Hau et al. 2017). A number of studies have dealt with efforts in hospitals to improve their service quality and increase consumer satisfaction (Hong and Lee 2017; Hyer et al. 2009). For example, Lee et al. (2016) showed relationship between hospital's system to prevent medical error and medical error reduction. This study was conducted based on survey approach. The majority of the studies in hospital quality domain were conducted based on survey research or simulations. Especially most of studies were conducted to develop simulation models to suggest solution for emergency room (ER) activities (Blake et al. 1996; Jack and Powers 2004; Green et al. 2007). Prior studies have suggested that an ER, which faces "time varying demand" (Green et al. 2007), is the hardest department in the hospital to manage because of unpredictable demand (Jack and Powers 2004), and it can be a bottleneck in hospital systems. Many of those papers have attempted to find a solution for staffing issues and to develop simulation models for the ER which can be adjusted to various situations (Sinreich and Marmor 2005).

Most of the research done in an ER domain has overlooked the importance and unique features of human resources (Grönroos and Ojasalo 2004). The researchers assumed that the workforce in an emergency department operates at a constant production rate, and developed their model to describe the phenomenon (Sinreich and Marmor 2005). This stream of research assumed service rate as an exogenous factor when designing service operations. Unlike manufacturing production rates, service production rates are highly dependent on HR and cannot be constant over time (Oliva and Sterman 2001; Zeithaml et al. 1990). Accordingly, without considering the "dynamic and nonlinearity" feature of HR production rates, managers in an ER can have trouble managing its HR effectively. Hence, this research seeks to identify and examine such characteristics of service productivity in the context of hospital emergency room whose productivity tends to heavily depend upon human resources (Blake et al. 1996; Dittus et al. 1996; Post and Kagan 1998; Sinreich and Marmor 2005).

A prior study has identified work pressure or work intensity as the primary cause for the nonlinear characteristics of service productivity of human resources (Kim et al. 2006; Kc and Terwiesch 2009). Our research takes the burnout effect in the ER into consideration, and attempts to show burnout to be another cause for such characteristics. As work pressure intensifies, the productivity of human resources tends to increase in order to keep up with the increased intensity. However, when work schedule's intensity reaches a certain level, service productivity of human resources can decrease due to such reasons as accumulated fatigue. We simulate this burnout

phenomenon and demonstrate the existence of such factors in emergency rooms. Our study depicts the real system much more closely by using the system dynamics simulation model, and we contend that our simulation tool is an effective method to deal with the burnout factor. We also proposed improved simulation model to suggest solution to run emergency room.

This study is organized as follows. Section 2 provides a comprehensive literature review concerning characteristics of ER, burnout, and system dynamics. Section 3 describes the system dynamics simulation model. Section 4 summarizes the simulation results and Sect. 5 proposes the study's academic implications and conclusion. Finally, Sect. 6 describes the limitations and future research directions.

2 Literature review

2.1 Characteristics of ER

Many recent studies related to service productivity have been conducted in various service productivity systems. Interestingly, an emerging body of studies has addressed the medical service productivity system (Hyer et al. 2009). In particular, many recent studies have focused on ER management. ER has considerably disparate characteristics due to environmental factors, unlike other departments in hospitals (Weichenthal et al. 2016). Medical institutions are committed to further efforts on the build-up of the emergency medical system and the management of the ER doctors and nurses (Jennings et al. 2015). Significant numbers of patients transferred to the ER are mostly victims of emergency or trauma caused by sudden accidents; therefore, it is necessary to establish a systematic process with the patient's waiting time and length of stay at emergency as the core values of operation (Ferrin et al. 2007; Di Somma et al. 2015). The length is significantly associated with overcrowding and waiting time of the ER (Mason et al. 2012). Failure to respond rapidly and shorten the length of stay at emergency department makes it difficult to perform the functions of the emergency medical center, and improve patient experience and satisfaction (Vermeulen et al. 2015). If the length of stay at emergency department gets longer, the medical staff hardly concentrate on the medical activities due to the work overload (Johnston et al. 2016).

Managers should consider three factors such as the input, throughput, and output factors in order to effectively establish an ER process (Boyle et al. 2012; Smith et al. 2016). The input factors include the number of patients in the ER and the type of severity. The throughput factors are ratio of ER patients to staff, and the length of stay including waiting time and treatment time. Lastly, the output factors are boarding time, available hospital beds, ICU beds, and patients waiting for admission. Some emergency departments have bottlenecks in their operating processes due to insufficient discharge planning, despite managing and controlling the three factors (Asaro et al. 2007). Many studies have been conducted to figure out solutions for the length of stay, overcrowding, and long waiting time in the ER. The application of lean six sigma can reduce unnecessary processes and waste in emergency medical services (Damato and Rickard 2015; Yaduvanshi and Sharma 2017). The tools

based on theory of constraints enable hospital managers to resolve the core problems such as long wait times, ambulance refusal, and prolonged pain for waiting patients (Rutman et al. 2015; Bisogno et al. 2017). Developing ER key performance indicators (KPIs) is important because KPIs can control various dimensions such as safety and timelines (Rahmlxan et al. 2015; Strudwick et al. 2015). It is also crucial to employ service design that is patient-friendly, and in the same time beneficial to improvement of ER (Steinke 2008; Pitt et al. 2016).

The usage of ER resources is limited because the demand is generally uncertain (Vieth and Rhodes 2006). Also, even if ER has built a systematic process, patient complaints may arise and ER violence may occur due to factors such as long waiting time, patient intoxication, patient recovery potential, and anxiety in emergencies (Bragard et al. 2015). Doctors and nurses in the ER do not have sufficient time to give each patient enough explanation (Cho and Kim 2014). Since they have to prioritize in providing first aid by classifying patients according to the severity, the ER patients easily feel dissatisfied with the medical services (Lee and Ahn 2015). In addition, most of the ER patients are unstable because they are mentally and physically insecure due to sudden accidents or illnesses (Barreto et al. 2017). Because staff members of the ER department deal mainly with emergency situations, they are exposed to psychological risks due to the intensity of high work, lack of rest time, excessive demands of the patients, and insufficient compensation system (Cho and Kim 2014; Chung et al. 2010; Lee and Ahn 2015; Rozo et al. 2017). ER workers frequently or repeatedly experience burnout because they feel pressured to provide rapid and accurate judgment in high emotional stress situations (Baek 2009; Azoulay and Herridge 2011; Adriaenssens et al. 2015). Medical staff who repeatedly experience burnout become dissatisfied with their work, which in turn leads to inefficiency and lower productivity (Rozo et al. 2017). Burnout has a significant influence on the turnover, demotivation, dissatisfaction, and job immersion of the medical staff (Adriaenssens et al. 2012; Cho and Kim 2014).

2.2 Burnout

Maslach (1982) developed a measure for the effects of burnout, which weighs the effects of emotional exhaustion, depersonalization, and reduced sense of personal accomplishment. Emotional exhaustion is a chronic state of both physical and emotional depletion by one's work (Schaufeli et al. 2001). Hence, exhausted employees would not be able to properly deal with customers as well as they would in a normal condition (Crawford et al. 2010). Depersonalization is an alteration in the perception of the self so that people feel detached from their mental processes or their own physicality (West et al. 2012). Employees who experience this symptom respond to the customers with skepticism or become inattentive to them because employees with the symptom treat customers as an objective, not as a human being (Shih et al. 2013). Reduced sense of personal accomplishment is a state where one recognizes self-development as a negative activity because of his or her work (Shanafelt et al. 2015). Under the effects of this symptom, employees underrate themselves and lose excitement in their job (Nahrgang et al. 2011). As interests in burnout increased,

many empirical studies on the issue have been followed (Jackson and Maslach 1982; Shirom 1989). They claim that due to burnout, absence, and turnover often occur, productivity decreases, and workers' ability to think was reduced (Jackson and Maslach 1982; Shirom 1989). They also assert that understanding the causes and results of burnout is required for effective control and management of service operations systems.

Burnout is a multidimensional problem caused by multiple causes such as role and work overload in work environment, time pressure of work handling, contacts with difficult customers, work schedule, and work environment (Maslach and Schaufeli 1993; Demerouti et al. 2001). The higher the stress caused by job performance, the lower the job satisfaction and result the negative effects such as depression, anxiety, and burnout (Karatepe and Sokmen 2006; Jawahar et al. 2007; Adriaenssens et al. 2015). Demerouti et al. (2001) pointed out that burnout is caused by physical work overload, time pressure, repeated contact with demanding customers, physical environment, and business schedules. Schedule pressure has an influence on the time per task. Excessive job demands make workers finish their jobs faster. However, excessive work load can cause side effects. According to Sterman (2000), increases in schedule pressure lead to increases in working weeks and decreases in time per task. He also asserted that there was a nonlinear relationship between working weeks and time per task, supporting Oliva's (1996) findings. Figure 2 demonstrates the nonlinear relationship between schedule pressure and its effects from Oliva's (1996) study.

Previous studies demonstrated a significant increase in fatigue levels of the people and accordingly a drop in the workers' productivity (Homer 1999). The empirical tests concluded that an excessive scheduled pressure leads to a decrease in outcomes, but did not convey any significant, specific relationships among them. Oliva and Sterman (2001) explored the relationship between burnout and work outcome on bank employees. Specifically, this study revealed that the banker's working process becomes slower as work load per hour exceeds a certain level, as shown in Fig. 1. The nonlinear curve steadily rises until it meets the straight line. Beyond that point, the nonlinear curve gradually goes downhill. This confirms that work process per hour increases as work schedule pressure becomes tighter until point A and then the work process per hour decreases, in other words, the worker is burned out by the excessive work load.

The experience of burnout among medical workers has been the focus of much research during the past few decades. ER workers are perceived to be particularly sensitive to the risk of burnout due to high work stress because they deal with emergency situations (Adriaenssens et al. 2015). Also, as the satisfaction in medical services has become more important in recent years, the intensity of demand for emotional labor has increased (Bailey et al. 2011). Job dissatisfaction of the employees increase as the intensity of emotional labor increases and the emotional burnout deepened (Hochschild et al. 1983; Schaufeli and Bakker 2004). Burnout among ER members may occur often and may become more severe over time (Bragard et al. 2015). The percentage of medical staff experiencing burnout is getting higher because of lack of countermeasures developed by medical institutions (Adriaenssens et al. 2015). There have been reports of high burnout of emergency medical staff in

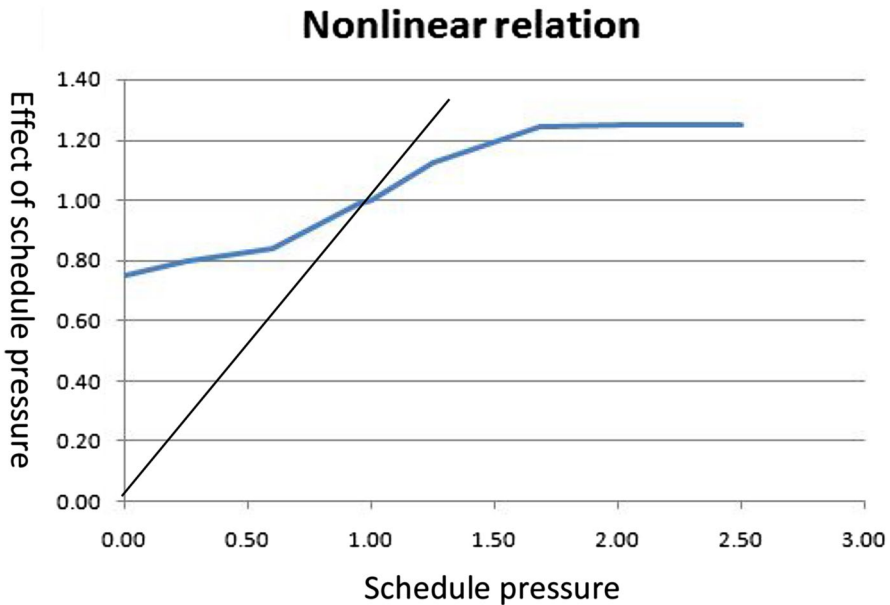


Fig. 1 Nonlinear relationship between schedule pressure and productivity

many countries. Doctors who are stressed, burned out, and depressed cannot achieve what they desire, assuming that an individual is no longer making meaningful contributions to work or interaction with people, resulting in self-denial, low morale, absenteeism, and decreased productivity (Wallace et al. 2010).

Burnout can be alleviated by job resources such as securing compensation fairness, superiors' support, colleagues' support, and job autonomy (Karasek and Theorell 1990; Demerouti et al. 2001; Bakker et al. 2005; Smith and Clark 2011). Therefore, medical institutions need to establish a long-term management plan that allows employees to feel pleasure or sense of accomplishment or feel their presence (García-Izquierdo and Ríos-Rísquez 2012). It is important to develop a training program that can develop accurate and smooth communication skills, and establish a plan to effectively communicate openly in the organization (Bragard et al. 2015).

2.3 System dynamics

Simulation has been a favorite research method in the medical services field (Bresnan et al. 1988; Huang 1998; Machuca et al. 2007). Computer simulation software has made a huge contribution to increases in both efficiency and quality in emergency department operations (Saunders et al. 1989; Everett 2002). The simulation can be animated on a personal computer monitor showing simulated patients, specimens, and staff members moving throughout the ERs (Harper 2002). Smith-Coggins et al. (2006) examined whether a 40-minute nap opportunity at 3:00 in the morning can improve cognitive and psychomotor performance in physicians and nurses

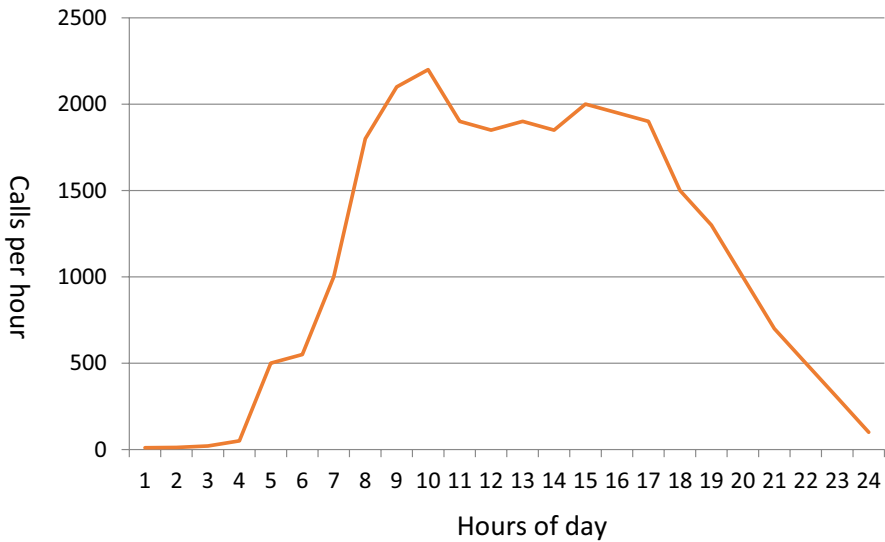


Fig. 2 Demand pattern variation during a day

working 12-hour night shifts. What their study discovered and interested the readers was that the researchers took the degree of fatigue into consideration in order to evaluate the productivity of workers. This study, however, focused only on fatigue or tiredness in the simulation model for the emergency department excluding schedule pressure. Kim et al. (2006) recently conducted simulation research using a new approach that views the hospital as a unified system, and uncovered the nonlinear relationship between schedule pressure and outcomes. They suggested that variation in patients during the day is large enough to cause problems (Green et al. 2007). Figure 2 shows a variation with demand in their research.

A particular effect occurring in a certain system is an outcome of interactions among various elements of the given system. If the number of elements become more than three, it is difficult to predict those effects. Such prediction becomes even more difficult in the real world because of the interactions of hundreds of elements. System dynamics, a computer simulation modeling technique for structuring and understanding the behavior of complex systems over time, illustrates the interactions of complex elements with nonlinear functions (Sterman 2000). In this sense, system dynamics is a useful methodology for solving complicated issues that need to deal with dynamic activities of variables when the feedback to the response of the system is very important (Sterman 1989; Brehmer 1992; Funke 1991; Flessa 1999). Moreover, system dynamics is used for framing the causal effect of elements and analyzing the dynamic changes in the performance of enterprises after the organizations make strategic decisions (Sterman 2000).

System dynamics is based on closed loop thinking (circular feedback system) and the dynamic change of any variable caused by a circular causation (two-way causation or feedback) with the variables present inside the system (Karnopp et al. 2012). Since system dynamics emphasizes feedback between the components of the

system and the cyclical causal relationship, all causal relationships are regarded as cyclical relationships without distinction between dependent and independent variables (Azar 2012). The causal feedback loop consists of a self-regulating balancing loop and a self-reinforcing loop. A self-regulating balancing loop reliably causes the system to move to the target and a self-reinforcing loop causes synergistic effect to the system. The self-regulating balancing loop serves to stabilize the system, while the self-reinforcing loop has the characteristic of sustaining the system’s virtuous or vicious circulation cycle.

Based on the discussion, system dynamics is a useful approach to understand the emergency department in the hospital because there will be many feedbacks and various causal relationships of elements in the patients flow (Sterman 2000; Moon et al. 2004). Therefore, we adopted system dynamics simulation model in this research using Vensim DSS 6.3G.

3 Model

Since the purpose of this study is to make a more accurate simulation model of an ER, we took burnout effect into consideration in addition to the early studies that considered only work pressure on employees. Figure 3 presents the distribution of patients visit per hour, an interesting characteristic of an ER that distinguishes it from other departments in the hospital. The distribution shows that it is more likely that patients’ arrival dramatically increases during the evening hours. Accordingly, it is expected that there will be a significant increase in work pressure on employees in the same period. Thus, the emergency department can be an appropriate choice for observing the effect of pressure on workers (Green et al. 2007).

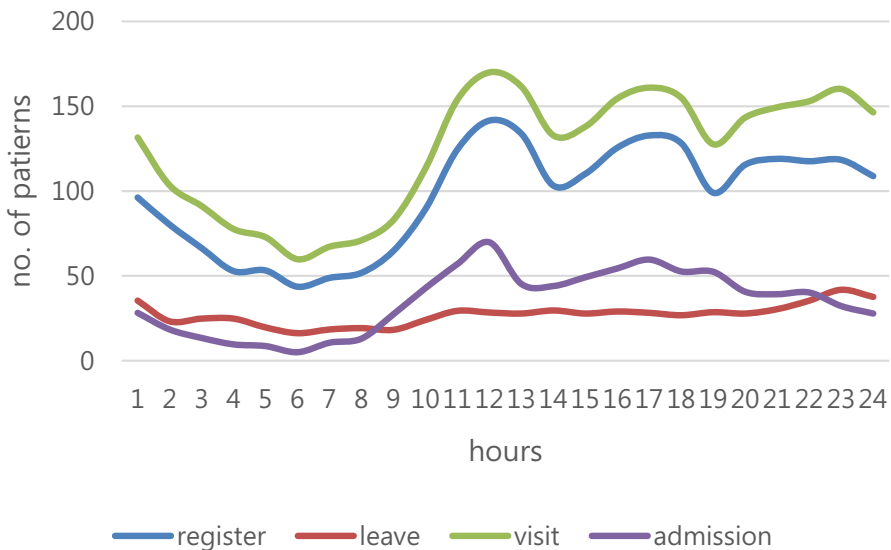


Fig. 3 Patients’ pattern from the dataset

Table 1 Input variables

Variables	Mean	SD
Patients (numbers/hour)	43	11.85
Work force (doctor and nurse)	10	1.00
Treat time per patients (min)	10	3.00

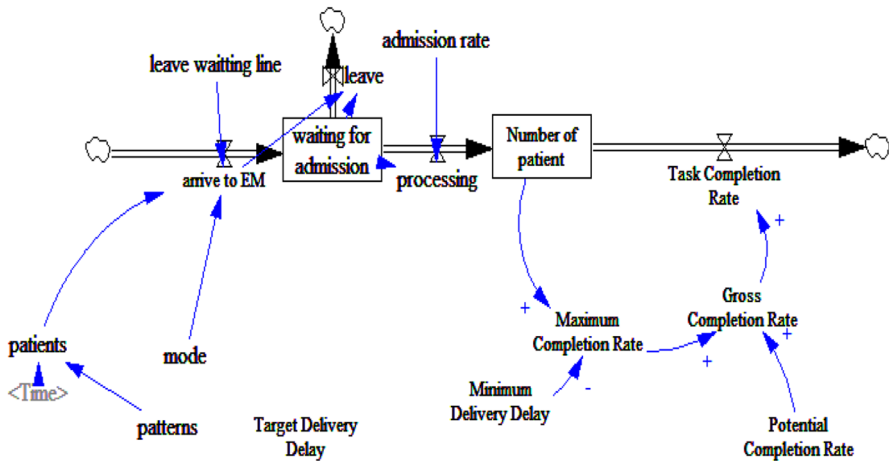


Fig. 4 Base simulation model for the emergency room

This study used hospital data from one of the largest hospitals, which has about 2,500 beds, in Seoul, Korea. This hospital is a higher-level general hospital with the local emergency medical center. Data used for the simulation are from the data collected from the emergency room and interview with the staff. Simulation ran a total of 256 h. We collected data for 256 h due to following reasons. First, we took advice from staff at hospital that 256-h period can represent characteristics (mean, variance) of patients distribution. Second, we only consider regular process of ER, thus, we also agreed distribution of 256 h is enough time window to analyze the model. Input variables of study model are depicted in Table 1. Patients in Table 1 refer to patients who arrived at the ER from real data. Work force includes 3–4 doctors and 6–7 nurses. This workforce consists of one shift for ER. Mean number of work force is 10 and average treat time is 10 min per patients. Based on these data, we first developed a base simulation model with a constant production rate, as shown in Fig. 4.

Next, we developed a model which included a work pressure loop as described in Fig. 5. In this model, the requested number of patients became a source of work pressure and it required the work force to rise above their capacity. This process increases productivity in short run. However, in same time, this process also creates fatigue to work forces. This “work pressure loop” reflect nonlinear effect of work pressure on outcome. Finally, we created a full model which included the burnout effect in addition to work pressure. This model is shown in Fig. 6 with the added

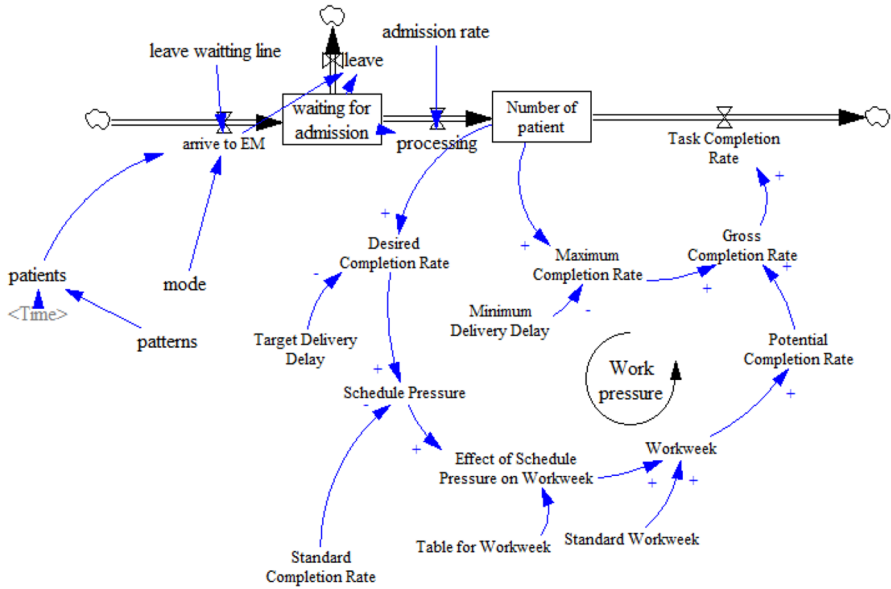


Fig. 5 Work pressure model

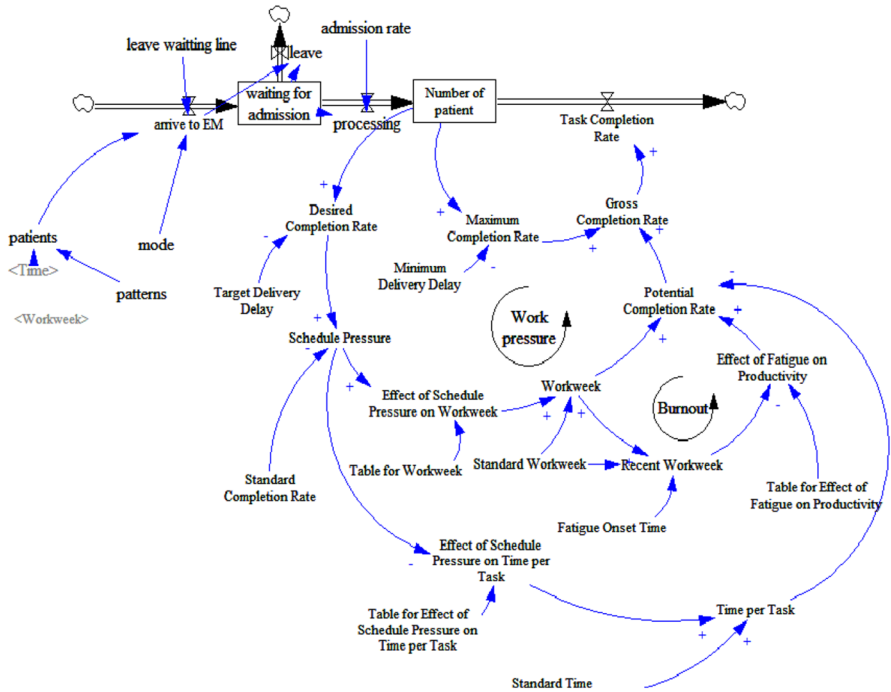


Fig. 6 Full model with work pressure and burnout

burnout loop to see how burnout affects the final production rate. This “burnout” loop is a feedback loop that shows nonlinear impact on outcome due to fatigue. If a staff work more than he or she can manage, productivity will decrease. This symptom might create unexpected managerial issue for the ER.

4 Results

In this study, the simulation model was developed to understand the behavioral characteristics of human resources in an ER environment. The actual data was compared with three different simulation model (i.e., the base ER model, the ER model which included effects of work pressures, and the ER model which included effects of both work pressure and burnout). Also, the number of patients generated from each different simulation was compared with the actual data to obtain reliability. In order to avoid bias for the analysis of ER operating system, we ran 840 times of the simulations to obtain the statistical power (1-beta) of 0.8 (Erdfelder et al. 1996). Then, we compared means from each replication with the actual data. The mean from each simulation [(1) the base model, (2) work pressure model, and (3) work pressure and burnout model] is the mean from 264 durations. The graph of the number of patients from simulation is shown in Fig. 7. It shows pattern of the patient load over 264 h, and the result is similar to the real pattern of patients in terms of 24 h.

Figure 8 shows changes of schedule pressure over time. Schedule pressure either decreases or increases depending on the number of patients in ER over the time period. Pressure greater than 1.0 means that the work force is asked to work more than their capacity. A certain degree of this pressure might positively affect work rate, but when it exceeds a critical level, it may decrease their production rate. In the actual system, treatment time per patient is greatly affected by changes in schedule pressures. As shown in Fig. 8, the number of completed treatments was also affected by changes caused by schedule pressure.

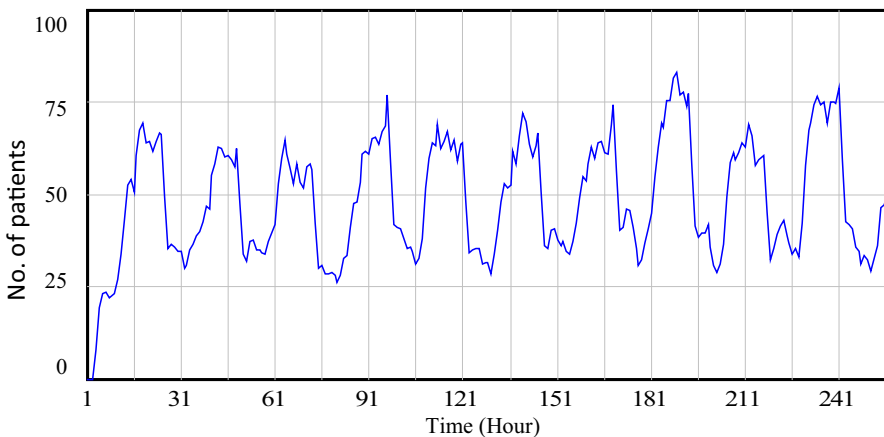


Fig. 7 Patient pattern from simulation results

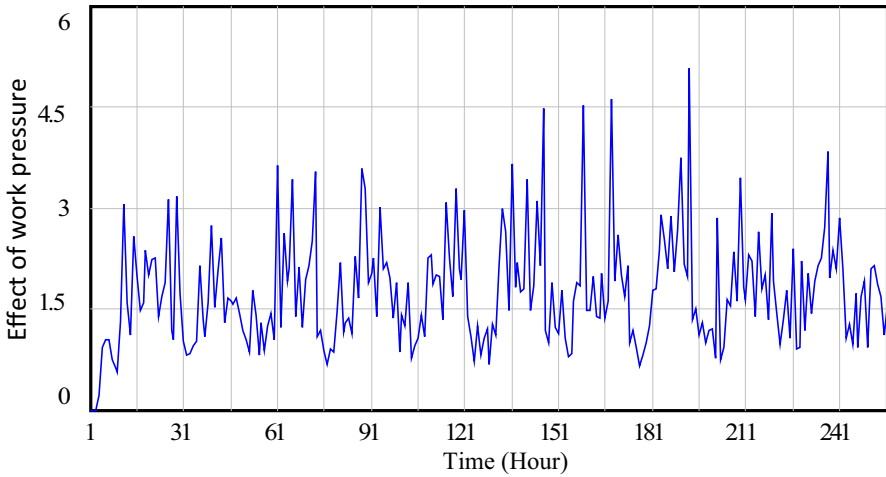


Fig. 8 Effects of work pressure

As shown in Fig. 9, fatigue reduces the amount of production which workers can deliver. A result that drops below 1.0 means that the work force was less productive than what it should be, due to fatigue and burnout.

Tables 2 through 4 show the results obtained after running 840 replications of the simulation model. Table 2 is the results for the base model which did not consider any of work pressure or burnout. Table 3 is outcome that compare real data and data from simulation model include work pressure, and Table 4 shows results including both work pressure and burnout. The results were then compared with the actual ER data. Average values of the two datasets were compared by using t test. There was a statistically significant difference between the base model and

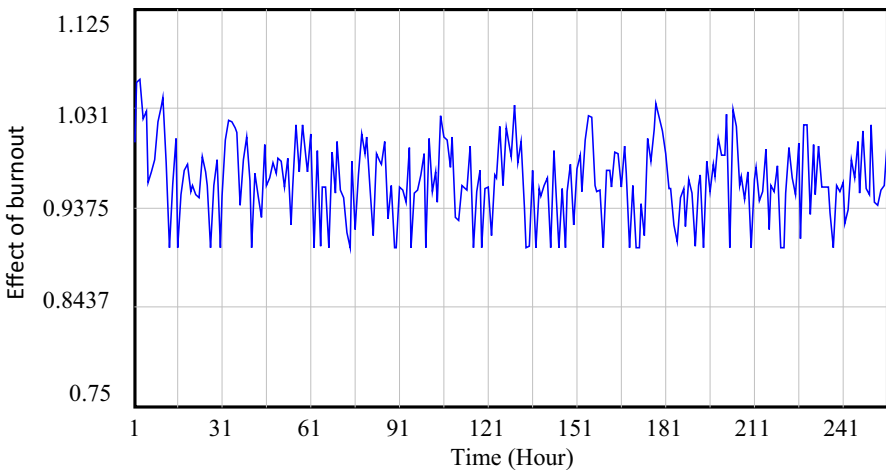


Fig. 9 Effects of burnout

Table 2 Differences between the real ER data and base simulation model

	Levene's test for equality of variances		t-test for equality of means		Mean difference	Std. error difference	95% Confidence interval of the difference	
	F	Sig.	t	df			Lower	Upper
Equal variances assumed	975.442	0.000	-81.918	1678	-35.14233	0.42900	-35.98376	-34.30091
Equal variances not assumed			-81.918	1004.784	-35.14233	0.42900	-35.98416	-34.30050

Table 3 Differences between the real ER data and simulation model (base model + work pressure)

	Levene's test for equality of variances		<i>t</i> -test for equality of means			95% Confidence interval of the difference			
	<i>F</i>	Sig.	<i>t</i>	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Equal variances assumed	54.747	0.000	-21.244	1678	0.000	-11.22505	0.52839	-12.26141	-10.18868
Equal variances not assumed			-21.244	1614.241	0.000	-11.22505	0.52839	-12.26144	-10.18865

Table 4 Differences between the real ER data and simulation model (base model + work pressure and burnout)

Levene's test for equality of variances		<i>t</i> -test for equality of means				95% Confidence interval of the difference			
<i>F</i>	Sig.	<i>t</i>	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper	
Equal variances assumed	1.204	0.273	-2.272	1678	0.023	-1.34167	0.59056	-2.49998	-0.18335
Equal variances not assumed			-2.272	1675.269	0.023	-1.34167	0.59056	-2.49998	-0.18335

the real data ($F=975.442$, $p<0.001$, Table 2). Also, comparison results between the real data and simulation model only with work pressure were significantly different ($F=54.747$, $p<0.001$, Table 3), though the difference was smaller. However, there was no significant difference between the real data and results from simulation which considered both work pressure and burnout with 0.273 p -values ($F=1.204$, Table 4).

Figure 10 shows the trend comparison among four datasets. In the figure, the simulation outcome line generated from work pressure and burnout is most similar to real data. The other two datasets do not show strong variation across time. This result also supports the previous analysis results.

We conducted trend analysis for statistical tests to figure out which relationship exists between the time and the number of patients. This result shows pattern of the data and can understand characteristics of data. According to real data, its relationship between the time and the number of patients can be explained by linear, quadratic, cubic, 4th, and 5th order term (Table 5). Data generated using pressure and burnout can also be explained in the same pattern (Table 6). This implies two datasets have similar data pattern. However, data generated from base model is explained by the fourth- and the fifth order terms only (Table 7). Also, data generated using only work pressure effect is explained by quadratic cubic and 5th order term (Table 8). Thus, trend analysis also statistically supports that data generated using work pressure and burnout effect equivalent pattern with the real data.

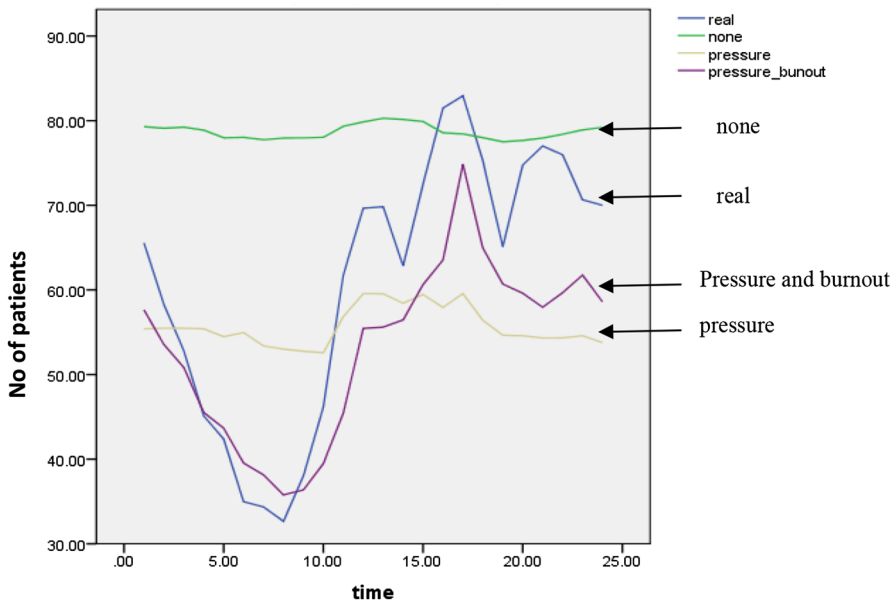


Fig. 10 Trend comparison among four datasets

Table 5 Trend analysis for the actual ER data

	Sum of squares	df	Mean square	<i>F</i>	Sig.
Between groups					
Combined	206088.833	23	8960.384	38.626	0.000
Linear term					
Contrast	96679.717	1	96679.717	416.766	0.000
Deviation	109409.116	22	4973.142	21.438	0.000
Quadratic term					
Contrast	2090.488	1	2090.488	9.012	0.003
Deviation	107318.628	21	5110.411	22.030	0.000
Cubic term					
Contrast	71661.057	1	71661.057	308.915	0.000
Deviation	35657.571	20	1782.879	7.686	0.000
4th-order term					
Contrast	9769.830	1	9769.830	42.116	0.000
Deviation	25887.741	19	1362.513	5.873	0.000
5th-order term					
Contrast	4283.722	1	4283.722	18.466	0.000
Deviation	21604.019	18	1200.223	5.174	0.000
Within groups	189282.650	816	231.976		
Total	395381.482	839			

Table 6 Trend analysis for the simulation model (base model+ work pressure and burnout)

	Sum of squares	df	Mean square	<i>F</i>	Sig.
Between groups					
Combined	86776.863	23	3772.907	17.085	0.000
Linear term					
Contrast	32409.324	1	32409.324	146.762	0.000
Deviation	54367.539	22	2471.252	11.191	0.000
Quadratic term					
Contrast	2927.945	1	2927.945	13.259	0.000
Deviation	51439.594	21	2449.504	11.092	0.000
Cubic term					
Contrast	35987.102	1	35987.102	162.964	0.000
Deviation	15452.492	20	772.625	3.499	0.000
4th-order term					
Contrast	1242.615	1	1242.615	5.627	0.018
Deviation	14209.877	19	747.888	3.387	0.000
5th-order term					
Contrast	7558.361	1	7558.361	34.277	0.000
Deviation	6651.515	18	369.529	1.673	0.039
Within groups	180196.099	816	220.829		
Total	266972.962	839			

Table 7 Trend analysis for the base simulation model

	Sum of squares	df	Mean square	<i>F</i>	Sig.
Between groups					
Combined	563.147	23	24.485	1.783	0.013
Linear term					
Contrast	5.006	1	5.006	0.365	0.546
Deviation	558.141	22	25.370	1.848	0.010
Quadratic term					
Contrast	1.030	1	1.030	0.075	0.784
Deviation	557.111	21	26.529	1.932	0.007
Cubic term					
Contrast	9.701	1	9.701	0.707	0.401
Deviation	547.409	20	27.370	1.993	0.006
4th-Order term					
Contrast	271.279	1	271.279	19.756	0.000
Deviation	276.130	19	14.533	1.058	0.390
5th-Order term					
Contrast	63.599	1	63.599	4.632	0.032
Deviation	212.532	18	11.807	0.860	0.629
Within groups	11204.661	816	13.731		
Total	11767.808	839			

Table 8 Trend analysis for the simulation model (base model + work pressure)

	Sum of squares	df	Mean square	<i>F</i>	Sig.
Between groups (combined)	4118.206	23	179.052	1.246	0.196
Linear term					
Contrast	36.629	1	36.629	0.255	0.614
Deviation	4081.577	22	185.526	1.291	0.167
Quadratic term					
Contrast	703.432	1	703.432	4.896	0.027
Deviation	3378.145	21	160.864	1.120	0.321
Cubic term					
Contrast	989.793	1	989.793	6.889	0.009
Deviation	2388.351	20	119.418	0.831	0.676
4th-order term					
Contrast	415.812	1	415.812	2.894	0.089
Deviation	1972.539	19	103.818	0.723	0.798
5th-order term					
Contrast	794.070	1	794.070	5.527	0.019
Deviation	1178.469	18	65.471	0.456	0.975
Within groups	117236.973	816	143.673		
Total	121355.179	839			

5 Conclusion and implications

This study developed a simulation model that can describe the ER environment more accurately by considering both work pressure and burnout effect. The results show that considering these nonlinear effects—work pressure and burnout—makes the simulation model more accurate and consistent with the actual observations in the ER. These findings imply that work pressure and burnout of employees are critical factor to influence the productivity of ER operations. Considering the stressful ER environment with various urgent cases, the results of our system dynamics simulation model might have potent reasons. Workers in the ER are often requested to do more work than they can handle, because of the imminent and irregular characteristics of their customers. However, this overload sometimes causes low service quality and failures in caring for patients. The ER workers' work schedule should be managed appropriately, because employees' work stress and job burnout are highly related to customers' satisfaction and loyalty in the service industry.

Previous studies have focused on suggesting optimal number of employees or capacity for the system, not considering dynamic feedback from the result of burnout or work pressure that leads to low production rate. However, this study incorporates nonlinearity and complexity issues with system dynamics approach. This approach contributes to previous literature by enhancing the understanding of interactions between important factors in the ER system. Since feedback loop involve time delays and behavioral responses that cause unexpected outcome, understanding interaction between factors has been complicated. Thus, reflecting human behavioral characteristics of the system provides a good comprehension of the system.

Many service operation managers may want to improve their performance by encouraging their employees to overwork. However, this approach can result in unintended effects such as low quality service outcomes that might need rework, leading to the low production rates and high operation costs. Fatigues of exhausted employees can also be a critical reason for the customers' dissatisfaction in the service industry, because only satisfied service workers can truly impress their customers. Due to the fact that the service firm's performance is up to its customers' satisfaction and loyalty, managing service workers' work pressure directly influences the firm's performance. In addition, service workers' workload is highly related to their customers' safety in such an urgent ER environment. Considering that the safety of patients is much more important than general customer satisfaction, ER workers' workload and the level of stress should be paid attention and managed carefully. Also, delays in this relationship between workload and outcome causes system hard to manage. This study describes embedded complexity in the system. Since decision making point and outcome from decision have some lead time, there is disequilibrium in the system and system dynamic approach captures this characteristics. Managers may acknowledge workload and burnout effect. However, it is not easy to control problems caused by nonlinear outcomes and outcomes that cannot be forecast. Thus, this simulation can provide insights and implications to ER managers by suggesting consideration of delays.

Over the last decade, hospitals have faced the hard economic condition because of the substantial increase in their expenses and fixed operation costs. Healthcare managers often needed to maximize the hospital's performance with constrained available resources. As a result, high utilization rate has been more important in the hospital and such a new environment sometimes makes hospital workers forced to overwork with more stress and fatigue. However, this study shows the evidence to support that hospital workers' excessive workload can be the critical cause of inefficiency in the hospital operations. Therefore, service operation managers should consider the side effects of employees' workload and job burnout, when they allocate their workers' capacity. If they fail to look into this matter, they might face unexpected problems whose reasons would be difficult to figure out.

This study designs the simulation model by employing the work pressure and job burnout to apply to the ER environment, but it can be applied to other service industries that have a large variation in input and output of operation processes. There has been a growing need to solve the complexities of the service business and difficulties in decision making processes among a variety of alternatives. The results of this study would provide meaningful implication in terms of connecting simulation tools to possible burnout effects of service employees which is one of the most critical operation problems in the service industry. Simplifying the ER environment, this study shows the effects of work pressure and job burnout in building the effective simulation model. If other factors in the individual service business are considered based on this model, it would provide more expansive insights to understand various managerial issues.

6 Limitations and future research

This study has several limitations to conduct for the future research. This study assumed work force staffing is constant during the time. One potential subsequent study would be to add hire and layoff decisions to solve the capacity and work pressure problems. This would allow us to see more dynamics of the system which can lead to unexpected results. Moreover, it can suggest a decision making rule that is able to propose the best policy to run an ER efficiently. Second, this study did not consider various possible characteristics of ER because it was needed simplifying the simulation model to effectively show nonlinear relationship between input and output in productivity due to the burnout effects. Future research may include various ER characteristics such as severity of symptoms, patient transferring to other hospitals, and day of the week to provide the detailed simulation effects. Third, this study developed a simulation model which showed current status of ER to describe the effects of work pressure and burnout on the efficiency of hospital operations, rather than showing a prediction model with more efficient way of ER operation. It would be interesting to suggest a prediction model with various improved operation ways in future research.

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