Qualitative Analysis in System Dynamics for Health Care System

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Abstract — System dynamics has been used as one of the simulation method to study complex system. The characteristic of system dynamics help researcher to see the relationship that may occurs in the health care systems. Although the implementation of system dynamics involves the use of both qualitative and quantitative methods, this study focus only on qualitative method. In system dynamics, qualitative data is necessary to identify the possible variable that can be used in order to develop a system dynamics conceptual model. Qualitative data in this study is basically obtained from the interview session that has been conducted throughout this study. Although the use of qualitative data may lead to the issues on data reliability and validity, one of the best ways to overcome this issue is through the method used to justify the data obtained from data collection. Therefore, this paper also discussed about the method used in order to analyze the qualitative data by using thematic analysis method so that it can be an input for researcher to develop a system dynamics conceptual model for health care. Besides that, this paper also discusses more details on how data from interview session was analyzed using four steps in thematic analysis.

Keywords – System dynamics simulation; qualitative approach; health care; variable for conceptual model

1. INTRODUCTION

System dynamics is one of the ways to gain more understanding on the complex system in certain areas and it is usually used to find any opportunity to improve the weaknesses and overcome problems. The history of system dynamics start on mid 1950s and was introduced by Professor Jay W. Forrester from Massachusetts Institute of Technology [1]. Jay Forester thinks that most of the problems in an organization come from the side of management and not the engineering part or industrial part. Therefore, when he was offered to be a professor in MIT School of Management which newly opened in 1956, he aimed to implement his study background in management area even his background study is in science and engineering. In his opinion, the combination of science and engineering might help in management area to study about the issues on the weaknesses in an organization and propose some ideas for the management improvements. Thus, he initiates the implementation of system dynamics by doing his hand simulation regarding on the structure of the stock flow feedback to show that the internal structure has caused the instability of employment in the organizations.

The idea of this paper is to study on how the policy implementation affects the use of workforce in health care. Therefore, it is important to identify the appropriate variables that can be used to develop a system dynamics model in order to see the relation among variables itself and make a dynamics hypothesis. The aim of this paper is to discuss about qualitative approach implemented in system dynamics simulation as well as to discuss about the method to analyze the data. Basically system dynamics implement qualitative and quantitative approach to build the model. Qualitative data help researcher to gain more understanding on how the dynamics interaction occurs in the system while quantitative data usually useful to develop a feedback models [2]. Besides that, expert also implement the use of system dynamics in order to see the behavior of the real system through the model and the results obtained from the study once it was tested with real world situation [3]. In the system dynamics model, there are three types of variables which consist of auxiliary, rate, and stock while for the flows it has two types which consist of information and material.

Throughout this study, researcher has successfully identified the output gained from the first process of implementing system dynamics, which named as problem articulation process. The output of this study is the variable that has been extracted from the interview transcript. These variables and flows are important to help researcher to do the second process in system dynamics in order to see the behavior of the real system through the interaction that occurs among the variables [4] and generate hypothesis. The variables used in developing system dynamics model was derived from qualitative data obtained from the analysis on qualitative data such as interview, observation and document analysis. Based on the qualitative data, researcher needs to do a suitable analysis to extract the data so that it can be meaningful information in the study as well as helping researcher to gain more understanding to the real situation. Due to its ability that can help researcher to study in the complex real world situation, system dynamics has been widely used by previous researcher in their study to analyze issues in regional planning [5], analyze issues related to operation management [6] and health care area [7]. As this paper basically discuss on method to analyze qualitative data to get variables, it should be noted that we only focus our study

on the first process of implementing system dynamics: problem articulation, as been elaborate in literature review section. In this paper, we present a case study of medical emergency coordination center (MECC) under emergency department in public hospital.

2. LITERATURE REVIEW

System dynamics has been widely used by previous researchers to study the behavior of the complex system. The ability of system dynamic approach to help modeler understanding the relevant factors that present in the system become one of the benefit for this technique. Moreover, the factor that has been found can be used by the modeler to find out the structure of the system and analyze the effects of different type of interactions [8]. In fact, some researchers claimed that system dynamics model also able to be used as a tools in financial management but it requires a lot of effort and is not easy to construct [9].

In modeling system dynamics approach, there are a few processes that has been highlighted [10]. This process basically was made in order to give the guideline to the researcher to go through the system dynamics simulation process. The flow of the process is shown in Figure 1.
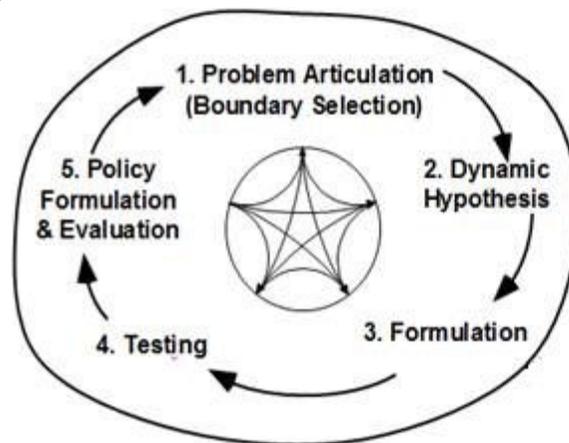

FIGURE 1: Process in system dynamic approach [10]

According to Figure 1, the five processes in implementing system dynamics are to help researcher to see the iterative process occurs in the systems. This iteration is used to show that each process are related to each other such the evaluation made on the fifth process should reflects the problem articulation that has been identified at the early process of the study. Each of the process may consist of its own necessary steps such as:

i. Problem articulation: The problem occurs in the real system was identified and researcher should consider the variable to be included and the concept of the study.
ii. Formulation of dynamic hypothesis: In this phase, researcher starts to formulate the dynamics hypothesis by looking into the consequences of the feedback diagram. In this process, the data derive from the qualitative approach should be included to generate the hypothesis [11].
iii. Simulation model formulation: To formulate the simulation model, researcher needs to identify the relationship among variables that has been identified in the systems.
iv. Testing: Testing process in the system dynamics approach means that researcher try to change the model into a certain unexpected condition which lead to the changes in the results on the systems. It also help researcher to see whether the model match or not with the problem that has been articulated at the early phase of the study.
v. Formulation and evaluation of policy: In doing the evaluation to the policy, the use of "what if..." question should be considered so that we can see different results for different conditions of the model.

A. *System dynamics in health care*

The task to manage health care is quite challenging since it consist of various stakeholders and many interaction occurs involve a different types of variable according to [12]. Therefore, it is necessary to use the system dynamics approach since it has the advantage to help researchers understand more about the complex system in health care. Besides that, the factor that contributes to the complexity in health care is the difficulty to understand the behavior of human factor which make it more challenging for the researcher [13].

However, most researcher implement system dynamics approach to study on the policy implemented in the health care. It may concern on the policy on assigning the roles for each staff in health care such has been done by [14] to see the functional group that may lead to the efficiency of the service in health care. Furthermore, a previous study done by other researchers about the implementation of system dynamics approach to study on health care fields has been identified in this paper and discussed the issues in the Table 1.

TABLE 1: Studies related to system dynamics in health care

Authors	Issues highlighted
[15]	System dynamics is used in order to predict the problem implementation as well as to share the idea to improve the results obtained from the study
[16]	System dynamics is used in a process of developing and managing policy in health care. The area of study that involve the use of system dynamics in this research are: -Disease screening -Health care workforce planning -Emergency health and social care development -Public health risk assessment
[17]	The process of formulation and calibration in system dynamics model was discussed in order to see the interaction that shows the pattern of demands, resources deployment in A&E, bed numbers and other different process in hospitals. The system dynamics model also runs for a few times by using a variety number of parameters.
[18]	Study on the use of system dynamics in order to investigate respond should be given with the increasing number of demands in health care up till it reach more than normal level.
[19]	The implementation of system dynamics simulation in order to study the possible impacts of strategies to reduce the cardiovascular disease burden in county and test the policy.
[14]	System dynamic simulation modeling was used in order to study the health care management as well as to lower the cost and improve the staff utilization for chronic disease.
[20]	This study focuses on hypothesis made on the operation execute by local health and social care organization in order to fulfill the demands of services and supply capabilities.

Although system dynamics has been used in the care by previous researchers, there is a gap which they did not clearly discuss on how the variable was identified in their study. Therefore, in this study more details regarding on how the variable in the system dynamics was identified and what are the suitable method should be used in order to analyze qualitative data was discussed. This paper is believed to provide an idea on how to extract the variable from the interview transcript.

B. Qualitative data in system dynamics

In the previous study that has been done by other researchers, they discussed on the implementation of qualitative method in doing system dynamics. It is because they found that qualitative research can help gaining better understanding on the culture of human and social in their real life environment [21]. In part of modeling conceptual model for system dynamics, previous researchers used qualitative method such as interview data to extract the causal influences and factor that can be used as an input to their model [22].

Besides that, this method also used by [23] to study about the unexpected effect of policy about community care. These examples of researcher give us information that the implementation of qualitative approach is used at the early stage of developing system dynamics model in order to form a description about dynamic hypothesis as well as the context of problem emerge in the real situations. Meanwhile, [24] use system dynamics in their study to find out the factors that may affect the quality in health care services and disability sector. On the other hand, [25] argue that it is important for the researchers to balance the use of qualitative and quantitative method and they should not fully depends on the input derived from qualitative method. The advantages and disadvantages of using qualitative method in system dynamics also has been discussed by [26] in his research.

In analyzing the qualitative data, [2] has discussed a few method that is suitable to be used to gain the input. Some of the methods are hermeneutics which used to find out the meaning of the culture's expression and how it connects each other. Meanwhile, [27] implement the hermeneutic method in their study to see the comparison among the themes in the case studied. Besides that, [28] implement the method of the grounded theory in their study to integrate and construct the reflexive and iterative analysis strategy. Apart from that, the thematic analysis also one of the methods used in analyzing qualitative approach. By using thematic analysis, researchers are able to gain understanding regarding the issues or idea to the problem in the study [29].

3. METHODOLOGY

In this section, we discussed on how this study was conducted in order to obtain qualitative data. It should be noted that although system dynamics simulation involves the use of both quantitative and qualitative approach, this paper only discussed about the part of qualitative approach in this study. Besides that, this section also discussed about thematic analysis as a method to analyze the qualitative data.

A. Qualitative approach

Qualitative method has been implemented in order to get clear understanding of the complex situation that occurs in the health care organization. This study was carried out in public hospital around Johor Bahru and focus on medical emergency coordination center (MECC) unit, under emergency departments. The purpose of the study in public hospital is to highlight the adoptions of system dynamics in health care systems. Besides interview, researcher also observes how staffs in the health care system manage calls received by their customers to report the emergency cases. Researcher also listens to the conversation that occurs throughout the phone call including the question asked by the call taker. The question asked basically by call taker is patient's information and condition. Then, call taker also give general guidance to the caller based on the medical dispatch card. Call taker also need to make a call to non-clinical team such as police. All this behavior is necessary for the researcher to know as it also contribute to the data collection for this study.

B. Interview

Using interview method can help researcher to ask question directly to the interviewee and interviewee also can respond directly to the interviewer without delaying the response time. Besides that, interview session also create the flexibility on both interviewee and interviewer to share the information related to study. On the other hand, interviewer should pay more attention on the answer given by the respondent in order to avoid any information missing. Therefore, researcher will bring together tape recorder during the interview session to record whole conversations with the permission from the interviewee. Recording the conversation are more accurate method to be implemented rather than only taking notes [30].

C. Interview respondent

Interview session in this study involve seven people from emergency department in the public hospital which involves specialist from emergency department and also staff that involve in emergency department operations. The selected respondent was chosen based on their roles and responsibility in emergency department because they have a better understanding on how the operation occurs in that particular department and more reliable information can be collected. Besides that, in this study related to emergency department, the scope of study is narrowed down into a policy that is implemented in the emergency department and to see the necessary variables.

- *Specialist.* The role of specialist in the emergency unit is to give the treatment to the patients once they arrive at the emergency department. Besides that, they also need to cooperate with staff from emergency department in order to synchronize the task. The purpose of interviewing specialist is to get the information on how they act when patients arrive at emergency department.
- *Nurse supervisor or sister.* The purpose of interviewing sister is to know how they act to help the medical officer or specialist in managing the emergency cases. One sister has been interviewed to share the information with the researcher about how task was given among nurses in emergency department.
- *Medical assistant*. Medical assistant basically was assigned to manage operation in emergency department. Five medical assistant was involve in this interview whereby the first person was supervisor in this department. Next session was involved call taker, person in charge in managing report and statistic in emergency department and other medical assistants. The purpose to conduct interview with them is to obtain a better understanding on the

situation or behavior of each staff while serving their customers and patients. It also help researcher to know the level of workload or work pressure, skill level and training in the emergency department.

D. *Thematic analysis*

In analyzing data obtained from the interview session, the thematic analysis method was implemented and the method that has been used by [31] was referred. In this study, there are four steps to conduct an analysis consist of:

i.   **Be familiar with the data**- Be familiar with the data means researcher have to read and re-read all the data and understand the exact situation occurs in the organization. Usually interview may be recorded using recorder, so researcher has to transcribe the discussion into transcript so that it will be easier to analyze.

ii. **Coding**- Coding in term of thematic analysis meaning that researchers have to organize data in a systematic and meaningful way. The process of coding just by hand whereby researcher needs to work using the hardcopy of transcript and highlight the important information with highlighters.

iii. **Searching for themes**- To search for themes, researcher has to recognize the pattern of the answers given by the interviewee. Basically, as this interview was done with a few people there must be certain term that repeated by other interviewee while answering the question. This step was showed in Appendix I.

iv. **Reviewing themes**- In reviewing the theme, researcher needs to make sure that the theme are relevant with the study and work with the entire data about emergency department. The variable emerged showed in Appendix II.

As thematic analysis was used in order to identify the variable in the emergency department unit, it is important for researcher to review that the theme obtained relevant to current study. A variable that has been identified in this analysis phase was used in the next phase implementation of system dynamics in emergency department.

4. RESULT AND DISCUSSION

Throughout this study, we have identified variables that are available in the emergency department that can be used in modeling system dynamics. As this analysis was done based on the four steps discussed in the previous section, we found that the variable start to emerge at the third step: searching for themes and then the variable was finalized in the fourth step: reviewing the themes. At the fourth step, the theme was summarized into a simple term that is easily to be understood by researcher and suitable to be used and implement in the system dynamics model. Table 2 shows the list of variables that had been identified.

TABLE 2: Variables in emergency department

No	Variable	Description
i.	Respond time	Time needed for emergency department to respond on the case reported by patients or customers.
ii.	Workforce	The number of staff available in emergency department to serve the patients.
iii.	Demand	Requests by customer or number of case reported by customer that requires the service from emergency department.
iv.	Involvement of non-clinical staff	The involvement of other agencies that may help emergency department such as JPAM.
v.	Teamwork	How the teamwork in emergency department was arranged to do the task in emergency department such as call taker.
vi.	Top level management	The involvement of top level management in implementing policy.
vii.	Provide training	Training provided for the staff in emergency department.
viii.	Improve skill level of staff	Staff in emergency department needs to be improved.
ix.	Facilities provided in emergency department	The availability of facility in emergency department that was used to serve the patients.
x.	The use of technology	Technology that was used to enhance the efficiency of the service from emergency department.

Based on the result obtained from the thematic analysis, we found out that there are ten variables that can be input to develop a system dynamics model. There are also certain elements or variable that may related to workforce in emergency department unit such as the use of technology and facilities provided in hospital. Besides that, we also found out that staff should have good skills to serve the patients and attend a training to enhance their knowledge. For the top level

management, they need to make sure that emergency department unit is properly managed by developing teamwork spirit for the staffs and providing policy as a guideline to their staff to serve the patients. The number of workforce also may affect the respond time in serving the patients. The involvement of non-clinical staff such as police or fireman may also become one of the variables that affect the health care system.

Next variable is the demand of the patients or customers who seek help from health care during the emergency. It can be seen that the number of demands in the health care reflect to the number of cases received by staff in the health care system. Therefore, we would like to study how these variables interacts each other and how the interaction occurs in this system may affect the use of workforce in emergency department unit.

In order to validate the variable used in this study, we asked for the co-operation from supervisor in MECC unit which part of emergency department to ensure that the variable is reliable. Apart from that, the variables emerged from the thematic analysis also revised for three times once we reach at fourth steps which is reviewing the themes.

5. CONCLUSION AND FUTURE WORK

Throughout this study, we have discussed about the use of system dynamics in health care and how the qualitative data obtained through this research has been analyzed using thematic analysis method. It should be noted that this study is concern on finding the variables that is suitable to be used in modeling the system dynamics model. Besides that, the process of conducting the thematic analysis by implementing four steps that has been discussed in the methodology section also briefly described in this study.

To expand the use of variable that has been identified in this research, we would like to further our study to the second phase of applying system dynamics by creating dynamic hypothesis in the health care system. In the next study, we will also discuss the involvement of quantitative method while developing and simulating the model.

APPENDIX

Appendix I

List of preliminary themes		
Abbreviations: Rsp = Respondent; Sp = Specialist; MA-S = Medical Assistant (Supervisor); MA = Medical Assistant; MA-St = Medical Assistant (Statistic); Sis = Sister		
Theme 1: Goals and outcome Codes: -Main goal is to ensure that public people receive a good service and living in health. -Define responsiveness and effectiveness as a main expected outcome from the goal that has been setup.	**Theme 2: Value and principles** Codes: -Giving a good service is a key to get a good return value from customers and aims for goals.	**Theme 3: Service delivery** Codes: -Misused the facility by the public people and cause limited number of facilities for other cases. -Customer complaining about the question asked during reporting the case. -Customers irritated because it takes a long time to answer all questions being asked. -Be professional and trying to make the caller understand the policy. -The important of gathering the necessary information. -Limited number of staff cause a delay in arriving at the reported location. -Less cooperation from public people not to give a way for ambulance.

Theme 4: Population	Theme 5: Context	Theme 6: Leadership and governance
Codes: -The number of population keeps up and down. -Many cases reported per day.	Codes: -Cooperate with non-clinical staff to handle certain cases. -Each action based on the policy and guidelines. -Involve in certain disaster mission may increase the workload in MECC.	Codes: -Each staff has their own roles and was supervised by the head of department or supervisor. -Leader should know their responsibilities and lead the operation in the MECC unit. -Each action should be based on the policy and guideline that has been provided in MECC unit. -At a peak time, staff should know how to act and give priority to the critical cases. -Policy was implemented in this unit. -Policy was modified based on the current situation in the hospital. -Policy was used to standardize the operation in all hospital. -The policy document was private and confidential.
Theme 7: Financial resources	Theme 8: Human resources	Theme 9: Infrastructure and supplies
Codes: -Manage by top level management. -Quite reluctant to talk about financial.	Codes: -Use work schedule to manage the operation in this unit.	Codes: -Facilities were very important. -Limit number of facilities affect the service given by MECC unit and increase the respond times. -Technology device is used to communicate among of each staff.
Theme 10: Knowledge and information		
Codes: -Training was given in order to improve the skill of the staff in MECC unit. -Information about the patients was organized properly. -Report was produced in order to inform the top level management. -Skills to improve effectiveness.		

Appendix II

Themes at the end stage		
Abbreviations: Rsp = Respondent; Sp= Specialist; MA-S = Medical Assistant (Supervisor); MA = Medical Assistant; MA-St = Medical Assistant (Statistic); Sis = Sister		
Theme 1: Goals and outcome Subthemes: -Deliver good service. -Responsiveness and effectiveness.	Theme 2: Value and principles Subthemes: -Deliver good service. -Receive a good value.	Theme 3: Service delivery Subthemes: -Respond time. -Lack number of staff (workforce). -Depend on cooperation from public people on road.
Theme 4: Population Subthemes: -High demand from public people.	Theme 5: Context Subthemes: -Involve in helping victim of disaster. -Cooperate with non-clinical staff.	Theme 6: Leadership and governance Subthemes: -Good leadership. -Policy implementation. -Good teamwork.
Theme 7: Financial resources Subthemes: -Relate to top level management.	Theme 8: Human resources Subthemes: -Work schedule.	Theme 9: Infrastructure and supplies Subthemes: -Facilities are important. -Technology device as a communication tool.
Theme 10: Knowledge and information Subthemes: -Provide training. -Improve skill level of staff. -Enhance efficiency.		

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