Defining System Boundaries

Applications to the Silent Alarm Design Problem

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Abstract

The discipline of systems engineering is often misunderstood by those who are not familiar with it. One of the main sources of this confusion is the ambiguity of the word 'system'. What defines a system? What is considered to be part of the system? When designing an engineering system it is important to be able to confidently define the boundaries of that system to enable clear communication of the scope and purpose of the design project. In this paper, the design problem of a silent alarm system for people with total hearing impairment in a workshop environment is used to demonstrate methods for defining system boundaries and purpose. A statement of goals and a system boundary chart are constructed for the silent alarm system and are used to discuss the merits of systems engineering methods in system definition.

Background Theory

In the preliminary design of a systems engineering project, one of the first steps is to define the engineering problem. Before any design can begin, it is necessary to know what the problem is, and to justify why it is an important problem. According to the International Council on Systems Engineering (INCOSE), problem definition may be in the form of a mission statement, a concept of operations or simply a description of the problem that the system must solve (INCOSE, 2006). Herrmann (2001) used a statement of goals to define the task of creating an information security program. A statement of goals is a list of problems that need to be solved or changes that need to be achieved, along with an appropriate justification for each. For example, one of the goals of the information security program was to 'Protect the privacy and integrity of customer records' and one of the justifications for this was that 'Customer loyalty depends on sound business ethics' (Herrmann, 2001). Whilst designing solutions to the engineering problem, each design can be compared to the statement of goals to check that it addresses each problem in the statement.

An appropriate problem definition statement leads the systems engineer to the next important step in preliminary design; defining the boundaries and scope of the engineering system. Defining the bounds of a system may seem trivial, but it is often difficult to identify what to include in a system and what is a part of the surrounding environment (Kossiakoff et al., 2003). Edwards (1990) explains that 'Drawing the boundary correctly is crucial to the design and implementation of effective systems – to solve a systems problem we must know what the system is.' As Edwards notes, complex systems tend to be much larger than originally thought, 'previously unconsidered factors may have considerable impact on the behavior of the system.' Hence one of the fundamental questions systems engineers must ask is 'What factors will affect the system's behavior?'

An appropriate tool for identifying the factors which influence a system is a system boundary chart. A system boundary chart defines the scope of the system by listing the factors and variables which are considered to be internal to the system, those which are considered to be external to the system, and those which are not considered at all (Sterman, 2000). These three categories are often labeled 'endogenous', 'exogenous' and 'excluded'. For example, a car drives on a network of roads and has its fuel tank filled at a service station. The car is dependent on and affected by the roads and the service stations, but an engineer cannot change the nature of the roads and the service stations to suit their car design. Hence the nature of the roads and the service stations would be considered external variables, whilst the type of tyres the engineer chooses (which must suit the road type) and the shape of the fuel inlet (which must be made compatible with service station fuel pumps) would be considered internal variables. It is important to catagorise the variables appropriately, because as Kossiakoff et al. (2003) explains, 'Many systems have failed due to miscalculations and assumptions about what is internal and what is external'.

Application and Discussion of the Theory

The engineering problem under investigation in this research paper is a silent alarm system for people with hearing impairment in a workshop environment. The silent alarm system needs to warn the user of a various dangers in the workplace, for example a reversing vehicle, a fire alarm, or alarms associated with power tools and machinery. The statement of goals below (Table 1) addresses three key purposes of the silent alarm system.

Table 1: Statement of Goals

Goal	**Justification**
The system must detect alarms in the workshop and alert the user in a timely fashion.	The safety of the user is of utmost importance. If the user is unaware of a reversing vehicle, dangerous machinery, or a fire danger they may be at risk of injury or death.
The system must not impede the user from performing their duties.	There is little point in solving the problem of the user not being able to hear alarms and at the same time introduce problems created by the silent alarm device itself.
The system must be applicable to	People with total or partial hearing impairments often have difficulty

various workshop environments and various alarms/warnings.	finding jobs due to communication and safety issues in the workplace. A successful silent alarm system will address this issue and help to improve the job prospects of those with hearing impairments.

The first and most basic goal states the fundamental purpose of the system, to detect dangers in the workplace and to alert the user accordingly. It may seem trivial to state this goal, but it is necessary to think about why it is an important goal to achieve. Whilst creating the silent alarm system the design must be continually assessed to ensure that original purpose has been preserved. The second goal is slightly less intuitive, as it addresses something the system must *not* do. It is the purpose of the silent alarm system to allow the user to operate at a higher level in the workplace than they currently do, so if the user can no longer perform their duties due to the silent alarm system, then the system is not achieving what it needs to achieve. The third goal broadens the scope of the project considerably, and prior to the construction of the statement of goals it had not been considered by the project group. This goal in particular has helped to develop the concept and design of the silent alarm system. The system design boundary chart below (Table 2) lists the variables which will affect the ability of the silent alarm system to achieve the goals from Table 1.

Table 2: System Design Boundary Chart for the Silent Alarm Design Problem

	Endogenous	**Exogenous**	**Excluded**
System design affected by variable	✓	✓	×
Variable affected by system design	✓	×	×
	Number of alarms/warnings that can be detected by the system	Number of hearing impaired workers in the workplace	Alarms/warnings outside of the workplace
	The range that the system can detect alarms/warnings over	Size of the workplace	The effect of temperature/climate on the functionality of the system
	The method of alarm/warning detection	Level of hearing impairment of the user	Alarm alternatives for vision impaired workers
	The method of user notification by the system	Severity of the alarms/warning that must be detected	Unforeseen/unpredictable emergencies (eg. natural disasters or medical emergencies)
	The source of power/energy for the system (if required)	Clothing/uniform/safety equipmesnt worn by the user	

The endogenous variables listed for the silent alarm system in Table 2 describe the capabilities and the utility of the silent alarm system. For example, one of the endogenous variables is the method the system will use to detect alarms and warnings in the workplace. The warning detection method for the silent alarm system is an integral part of how the system will operate, so it is important to make an informed and considered choice for this variable. The source of power for the silent alarm system is a variable that had not been previously considered by the project group. Since the construction of the system boundary chart, more thought has been put into this particular variable and the design issues it presents.

Exogenous variables affect the operation and design of the system, but cannot be changed to suit the system. An example of an exogenous variable for the silent alarm system is the level of hearing impairment of the user. It affects how the system might operate because different users will require differing levels of aid and different warning methods. In designing the silent alarm, it will be important to consider the needs of workers with varying levels of impairment. Previous to constructing the system boundary chart, the project group had not chosen the method by which the user should wear the silent alarm device. The clothing worn by the user was determined to be an exogenous variable (outside of our control) so it was decided that the device should be a versatile wristband/armband that can be worn by workers with short sleeves, long sleeves, no sleeves or gloves. By designing it in this way, the silent alarm device will be appropriate for workers regardless of their uniform.

Excluded variables are listed to aid in defining the scope and boundaries of the system. In order to create an efficient and well-defined system, it is important to not only know what is accounted for in the system, but also what is not accounted for. Systems engineering involves investigating and considering every aspect of the system, including its limitations, and the excluded column of the system boundary chart addresses this. One of the excluded variables for the silent alarm is the detection of alarms or warnings that might occur outside of the workplace, for example in a shopping centre or in the user's home. It is important that this variable is acknowledged because it assists in drawing a boundary around the scope of the engineering problem. Once the original goals of the silent alarm have been achieved the system can then be improved and developed, and the excluded variables provide a starting point for this. For the silent alarm design problem, a future improvement might be to create a universal alarm system that is compatible with fire alarms and other emergency warnings outside of the workplace.

Further Work and Conclusion

System boundary definition is part of a systems engineering stage known as preliminary system design (PSD). PSD has two distinct theories; system boundaries and system interfaces. The system definition techniques and system boundary charts discussed in this report are part of the system boundaries theory. During the next stage (system interface), a Functional Block Diagram (FBD) can be constructed. A FBD is a chart in which the system boundary is drawn around each of its subsystems, the components of each subsystem are drawn and the interconnections between them are displayed. When creating FBD it is crucial to know exactly where the boundaries of the system are and what factors will be influencing the system, so the system boundary chart is fundamental step in PSD. Figure 1 shows how these preliminary design ideas fit into the system engineering process.

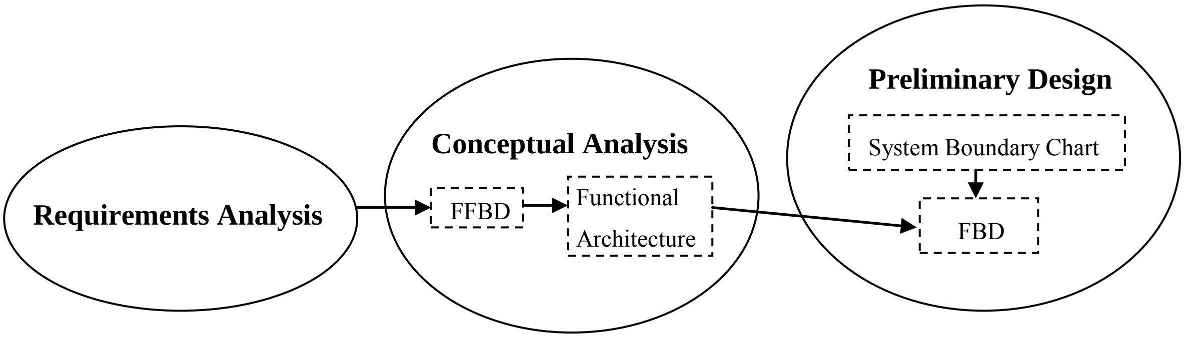

Figure 1: A diagram of how the system boundary chart and FBD fit into the systems engineering process

In this report the importance of a statement of goals and a system boundary chart in defining the purpose and boundaries of a system were demonstrated. The structured thought process used to construct the goal statement and system boundary variables led to the consideration of wider range of factors than were initially considered for the silent alarm system. The design of the silent alarm system will benefit significantly from this process.

References

Edwards, L., 1990. 'Beating the bounds (defining systems engineering boundaries)', *IEE Colloquium on Systems Integration: Principles and Practice,* IEEE.

Herrmann, D. S., 2001. 'A Practical Guide to Security Engineering and Information Assurance', Auerbach Publishers Inc. pp 67-82.

Sterman, J.D., 2000. 'Business Dynamics – Systems Thinking and Modeling for a Complex World', McGraw Hill, pp 97-99.

Shainee, M., Haskina, C., Ellingsen, H., Leira, B. J., 2012. 'Designing Offshore Fish Cages Using Systems Engineering Principles', *Systems Engineering,* vol. 15, no. 4, pp. 398-399.

Kossiakoff, A., Sweet, W. N., Seymour, S. J., Biemer, S. M., 2003. ‘Systems Engineering: Principles and Practice’, *Hoboken, NJ: John Wiley and Sons, Inc.*

Peer Reviews

Peer Review #1: Thomas Banks Sunday, 21 April 2013, 09:44 PM

Demonstrates that formatting requirements have been met:

Report needs to be shortened back to 5 pages (this should reduce the word count back to the maximum of 1500). Tables should have captions eg Table 1: Statement of goals or Figure 1: Statement of goals. I would also suggest putting your figure 1 (on pg5) at the bottom of "Further Preliminary Design Development". Ensure page numbers aren't too close to the text (see pg 5/6). A conclusion also needs to be added in. Otherwise, the formatting requirements have been met.

***Demonstrates a correct understanding of the theory*:**

An excellent understanding has been demonstrated in all sections of the report.

Application of the theory to the project:

Theory has been applied to the project very well.

Quality and relevance of bibliography:

References are all relevant and of good quality.

Suggestions on how could the paper be improved:

The paper is very well written, which makes the important task of cutting back the word count difficult. A suggestion would be to not re-explain what endogenous and exogenous variables are after your Model Boundary Chart. You explained them well in the Model Boundary Chart itself and in the Background Theory. Also consider shortening the part of the Theory Application section that addresses the statement of goals. Also consider cutting final 2 sentences of "Background Section". I would also reduce the font size inside your tables to free up even more space.

Do not shorten "Further Preliminary Design Development". If there's room at the end, add to it. The system interface is an important consideration of preliminary system design.

If there's room at the end after that, I would consider putting in another figure or a picture to aid readability. eg a picture of the silent alarm wristband, an FBD scaffold or an FBD for the silent alarm project. But don't worry too much if there's not enough room.

Other ways to improve the paper have been mentioned in previous comments.

Well done! This report has lots of potential

Peer Review #2: Brian Cho Tuesday, 23 April 2013, 05:10 PM

Demonstrates that formatting requirements have been met:

Most of the paper looks good, like the title, author details, fonts, margins, and sub topics. But on page 5 it seems that you've extended the bottom margin a bit. (when you cut down the essay don't forget to change)

Also, the conclusion is not included. Although the Further preliminary design development does wrap the context a little, there should be a separate heading on conclusion.

Figure 1 is done correctly, but the tables are not. The table should also have the same format with italics caption explaining the table at the bottom. The little heading 'model boundary chart' should be included there.

The page number seems the biggest issue, it is 5 pages including the references. It's one page too long

Demonstrates a correct understanding of the theory:

The theories are well explained with sufficient support. But it seems to focus too much on defining the engineering problem, and only on model boundary chart. The system interface is not explained. One solution is to cut down the statements of goals to add systems interface.

Application of the theory to the project:

Again, it doesn't to go in to system interface. FBD is a major part of system preliminary design. it should be included or explained why it was not included. Also, there seems to be a big focus on statement of goals (the whole page 3). It seems to take up too much space compared to its relevance to the theory. Also, the last paragraph of the application could fit to the discussion part very well rather than the application. Otherwise, all statements are supported sufficiently and in good detail.

Quality and relevance of bibliography:

The sources are high quality journals and articles. They've also been used in the essay well to support the author's claim.

Suggestions on how could the paper be improved:

The first issue is the page number with 1 ½ page longer than needed. Making the tables can into pictures and then inserting should help the formatting a lot easier. Technically, the context of the diagrams can be smaller than 12 fonts – shorten and will give a lot of space. At worst case, having an appendix for pictures can help a lot.

Discussion (further preliminary design) seems short (~100 words) when max n. words are 250, but this could be solved with last paragraph of application inserted to discussion.