# The Applicability of Human Factors Engineering Analyses in Retail Stores

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**Table of Contents**

**Main Paper**



**Appendices**

## Abstract

The U.S. Nuclear Regulatory Commission performs various human factors analyses for the safety and reliability of Nuclear Power Plants. Three elements of these analyses are functional requirement analysis (FRA), function allocation (FA) analysis, and task analysis. In retail stores, human factors analyses are rarely used due to the low-risk environment. However, because online retailers such as Amazon and Ebay are dominating the retail industry, physical retail stores need to become more efficient in order to maximize their profits while supporting customer safety. It is probable that application of FRA, FA analysis, and task analysis to retail stores may help to bolster efficiency and ensure customer safety. The purpose of this project was to assess the applicability of these analyses in physical retail stores. To accomplish this purpose, the FRA and FA (treated separately), and task analysis were performed using the data from Capital Caring Thrift Store in Northern Virginia. Interviews, site observation, surveillance of tasks, and engineering judgement were used for the analyses, and the setbacks and successes experienced were assessed to determine the applicability of the analyses. The results showed that 1) the FRA was applicable to a moderate extent due to the difficulty of decomposing functions and determining their parameters, 2) the FA was applicable to a great extent with its effectiveness at task delegation, and 3) the task analysis was applicable to a great extent due to the sheer number of components that could be completed using the data collection techniques. Overall, there were numerous sources of uncertainty, such as variability of tasks and limited or biased data from store personnel, that hindered the analyses' applicability.


## 1. Introduction

Human factors analysis is the assessment of the interactions between humans and

surrounding systems in order to optimize human well-being and overall system performance. Human factors engineering refers to the implementation of human factors concepts in the design of these systems. The U.S. Nuclear Regulatory Commission (NRC) has developed the Human Factors Engineering Review Model to analyze the extent to which an applicant for a nuclear power plant (NPP) design integrates human factors engineering (HFE) into its design process (NUREG-0711). This model includes 12 elements in four phases: Planning & Analysis, Design, Verification & Validation, and Implementation & Operation. Three of the elements are functional requirements analysis (FRA) & function allocation (FA), and task analysis.

Functional requirement analysis in NUREG-0711 is defined as “the indication of functions that must be performed to satisfy the nuclear power plant’s overall goals”, and function allocation is defined as the process of “assigning functions to personnel and automation”. FRA identifies the goals of a design, high-level functions, systems that perform the high-level functions, and the framework for the function allocation. FA addresses system functions that are allocated to either machines or humans depending on factors such as task demands and capabilities and limitations of humans and machines. FRA and FA are essential to the design of safety-critical systems such as NPPs. They have also been applied to other high-risk human-machine interactive systems such as air traffic control (Mattarei et al., 2015).

NUREG-0711 defines task analysis as the process of identifying “the specific tasks needed to accomplish HAs [human actions], and the information, control, and task support required to complete those tasks.” Task analysis includes identifying all human actions deemed important, identifying the tasks needed to complete these human actions, and illustrating what is required to accomplish the tasks (including time required for each task, estimated workload, abilities/knowledge needed, etc.). Similarly to FRA and FA, task analysis has been used in many other industries. For example, it is used frequently by teachers involved with special education (Carter et al., 1996).

FRA, FA, and task analysis are interconnected because they are used together to determine the tasks needed to fulfill specific functions or human actions, and how these tasks should be accomplished. These analyses constitute a significant component of the HFE model and provide inputs to the other elements of the model, such as human-system interface design and determination of staffing requirements. In addition, these analyses can be applied to many fields involving human-machine systems such as the aviation and education industries. However, one area that has seen little testing in its perceptibility to these analyses is the physical (as opposite to online) commercial retailing industry.

As of now, physical retail stores are experiencing a decline as online retailers such as Amazon and Ebay grow in prominence. In order to survive, physical stores need to find a way to maximize efficiency so that they can maximize their profits while ensuring customer safety. Many functions and accompanying tasks in retail stores help fulfill these goals. Given that human factors engineering can improve efficiency and enhance safety, The FRA, FA, and task analysis may be useful tools for achieving these goals. This is because the results from these analyses guide the implementation of elements in the HFE model that have a more direct impact on efficiency and customer safety. These elements include the treatment of important human actions, staffing and qualifications, training program development, procedure development, and human-system interface design. If the FRA, FA, and task analysis are completed thoroughly and the results are applied to these elements, they will serve to bolster a retail store’s efficiency and safety precautions. The purpose of this report is to assess the

applicability of FRA, FA, and task analysis to retail stores.

To test the applicability of FRA, FA, and task analysis in retail stores, a full analysis of a hospice care thrift store owned by the Capital Caring hospice organization was performed using the guidelines in NUREG-0711. A unique feature of the store is that all proceeds go towards hospice care. Also, the store is staffed by a manager and unpaid volunteers. The disparities between volunteers and regular staff are taken into account in the FRA, FA, and task analysis. The majority of the data collection for the analyses comes from in-person interviews of the store personnel (manager and volunteers) and surveillance of tasks in the store. The Results section of this report summarizes the information obtained through the analyses, describes the observations made during the application of the analyses, and includes the assessment of the applicability of the HFE analyses. The report also discusses the differences between retail stores and NPPs that afflict the application of the analyses, the lessons learned regarding the practicality of each analysis, and the limitations of the study. Finally, the detailed results of the FRA, FA, and task analysis are documented in the appendices.

# 2. Methods

## 2.1 Development of the analysis templates

Before starting the FRA, FA, or Task Analysis, the review criteria for each in NUREG-0711 were assessed for their appropriateness for the retail store. From this assessment, components of the analyses that were inapplicable were excluded from the study. Next, templates that included the appropriate components from the review criteria were created. Table 1 presents the excluded components with justification and a list of the components incorporated into the study.

Table 1: The analysis components from NUREG-0711

| Analysis | Incorporated Components | Excluded Components |
|---|---|---|

| | | |
|---|---|---|
| Functional Requirements Analysis and Function Allocation | -Decomposition of high-level functions into the processes, store systems and components, and human actions that facilitate the functions<br><br>-The purpose, the conditions indicating need for the function, and the parameters indicating availability, operation, success, and terminability of each high-level function<br><br>-Function Allocation with technical bases for each allocation<br><br>-Assessment of responsibilities that personnel need to assume when monitoring an automated system<br><br>-Identification of all relevant safety functions, the requirements of each function, and the allocation of each function based on human strengths and limitations | -All assessments of modifications or changes between the functional hierarchy of the predecessor store and the current store (i.e. Function Allocation based on operating experience)<br><br>*Justification:* The store's design has not changed significantly enough for these assessments to be meaningful<br><br>-Definition of the system configurations or success paths for each function.<br><br>*Justification*: The system configurations and success paths are not complicated enough to warrant this kind of assessment<br><br>-Description of the overall role of personnel<br><br>*Justification:* The store personnel have to perform myriad tasks in the store so it is very difficult to determine their "overall role." |

| | | |
|---|---|---|
| Task Analysis | -Identification of tasks that represent the full range of store operating modes and that cover most of the considerations under (1) in the 5.4 Review Criteria (NUREG-0711) (many of the tasks that address the considerations are combined to simplify the analysis)<br><br>-Description of the screening methodology<br><br>-Task characterization: Decision-making, Response, Teamwork and Communication, Workload, Task Support, Workplace Factors, Situational and Performance Shaping Factors, and Hazard Identification<br><br>-Identification of the relationships among tasks, the number of people required for each task, and the knowledge and abilities required for each task<br><br>-An estimation of the time required and time available for each task that is based on data from personnel interviews, surveillance of tasks, and engineering judgement<br><br>-The selected tasks cover cognitive elements such as diagnosis and selection of appropriate response<br><br>-Identification of the alarms, information, and controls needed to accomplish each task: Because the vast majority of the tasks performed are performed under manual control, alarms, information, and controls are rarely needed | -All assessments of modifications or changes between the functional hierarchy of the predecessor store and the current store<br><br>*Justification:* The store's design has not changed enough for these assessments to be significant<br><br>-The staffing required for each task<br><br>*Justification:* Because the vast majority of tasks only require one trained personnel member, the number of personnel required was set at (at least) 2 in order to account for incapable volunteers<br><br>-Identification and consideration of the design characteristics of existing Human-System Interfaces (HSIs)<br><br>*Justification:* The cash register and credit card machine are the only two machines that have HSIs; neither is complex enough to warrant consideration |

| | | |
|---|---|---|
| | -Usage of techniques to analyze time required and minimize uncertainty and bias | |

## 2.2 Data collection

In-person interviews, site observation, surveillance of tasks, and engineering judgement were used to collect the data for the FRA, FA, and task analysis.

For the in-person interviews, two volunteers and the store manager each participated in an interview addressing the eight high-level store functions identified. For every high-level function, two questionnaires were developed to address all the important aspects of the analyses. One questionnaire was designed for the manager and the other was designed for two different volunteers. The questions for the manager focus on the specific components included in the analysis templates and procedures for the volunteers to follow. The question sets for the volunteers assess their knowledge of the specific components and procedures as well as their responses to the different high-level functions. Each questionnaire was approximately 20 questions long and featured both open-ended questions and rating questions on a rating scale such as 1 to 5. The questionnaires for all the high-level functions can be found in the Appendices.

Site observation and task surveillance were primarily used for the task analysis. Both were used to understand the procedures and specific tasks accompanying each routine high-level function. Yet, they could not be used for the safety functions that occur infrequently. When surveilling tasks, most tasks were monitored three times and a stopwatch was used to measure the required time for each task. The three measurements (in seconds or minutes) were then averaged and the result was used as a baseline to which a time margin was added. Some tasks could not be timed because they occured in a split second or took so long that measuring the time required would be impractical.

I, the author of this report, also used engineering judgment to supplement the information for the analysis components If the interviews or site observation/surveillance of tasks did not procure needed information. Engineering judgement was used primarily when common sense or basic knowledge of the store's operation was required (Strigini, 2002). I had one and a half years of experience as a volunteer in the store and had observed the various tasks and functions that the personnel in the store must accomplish. Thus, I possess the skills and knowledge to make judgements regarding the store's operation.

## 2.3 Procedure for the analysis

### 2.3.1 Functional Requirements Analysis

The goals of the store were identified as generating a profit and ensuring customer safety. These goals are ubiquitous in almost all retail stores. Next, the high-level functions were identified and classified as either routine functions or safety functions. Routine functions are those that are performed regularly in the store to generate a profit. Identification of the routine functions was conducted based on the information collected from the surveillance of various tasks in the store. Safety functions are those that are performed in the case of an emergency to ensure customer safety. The safety functions were identified based on assessments of the characteristics of the store and past incidents. Then, the incorporated analysis components in Table 1 were used to develop a template for the FRA, and the various data collection techniques were used to ascertain the information needed to complete the template.

### 2.3.2 Function Allocation

First, a template was developed for the FA. The template included a description of the current function allocations in the store and the assessment of the optimal function allocation for each high-level function. All of the data collection techniques were used to determine the current function allocations. To determine the optimal function allocations, multiple factors including the cost of automation, the capabilities of humans versus machines, and the complexity of tasks were assessed.

### 2.3.3 Task Analysis

First, a template for the Task Analysis was developed based on the incorporated components. Then, the tasks required for each high-level function were chosen based on whether failure to complete the tasks would lead to probable failure of one or more high-level functions. Then, the information needed for the task analysis was collected using the various data collection techniques. In particular, a task diagram was developed for each high-level function to delineate the key tasks needed to accomplish the function.

## 2.4 Documentation of the results

After the FRA, FA, and Task Analysis were completed, the task diagrams, templates, and interview questionnaires were documented according to the high-level functions. Subsequently, the results of the analysis components for each high-level function were added to separate documents. All the documents are presented in the appendices, with each appendix for one function. The content of each appendix is organized in the following order: The task diagram for each function, the details of the functional analysis, the results of the FRA, the outcomes of the task analysis, and the interview questionnaire including both the questions asked and the summarized interviewee responses. Section 3 of this report summarizes the main results.

# 3. Results

## 3.1 Functional analysis

Through surveillance of tasks, the overarching process for how merchandise is acquired,

distributed in the store, and finally sold to customers was identified. Essentially, merchandise is donated to the store by donors and is then organized in the back of the store. Then, the donated items are priced and distributed in the store. Then, the personnel conduct the checkout process where the merchandise is sold and the store makes a profit. In addition to conducting this basic process, the personnel also try to ensure customer loyalty by cleaning and organizing the store, and by helping the customers whenever possible. Because customer loyalty results in returning customers who buy more and help the store generate a higher profit, the tasks that are aimed at ensuring customer loyalty were included in the routine functions.

The routine high-level functions include the following:

- Receive and price merchandise
- Distribute merchandise and clean
- Aid customer at checkout

The safety functions identified address potential risks within the store as well as past incidents that threatened customers' safety. The most common emergencies that have occurred in the store are fires, medical emergencies, and robberies or shopliftings. The high frequency of these incidents and their potentially severe consequences relative to other potential safety threats warranted the safety functions.

The safety functions include the following:

- Detect fire and notify others
- Respond to and contain fire
- Help customers with a medical emergency
- Identify and respond to a robbery

The first two functions are both related to fire. The reason of having two safety functions that deal with a fire threat is that the two functions are typically performed by different people, different systems, and at different times and locations. Also, the fire alarm system and accompanying pull stations require additional planning and decision-making. The other safety functions are not split because the detection and notification of a health emergency or robbery is not as complex as that of a fire emergency.

After the high-level functions were defined, the FRA and FA templates were used to organize the data for the analyses. The functional analysis template adapted from NUREG-0711 includes the following components:

- The processes, systems, components, and human actions that are used for each high-level function
- The purpose and conditions indicating need for each high-level function
- The parameters indicating availability, operation, success, and terminability (possibility of

completion) of each high-level function

Each function is analyzed according to the dimensions above. The detailed results of the functional analysis are documented in the Appendices. Each appendix is for one function, and each typically has five sections: task diagram, functional requirements analysis, functional allocation, task analysis, and the questionnaire used to collection data/information. The tables below show the FRA results for the function “Detect Fire and Notify Others.” Table 2 shows the decomposition of this function into its respective processes, systems, components, and human actions. Table 3 shows the conditions indicating the need for the function and its availability, and table 4 shows the parameters indicating the operation, success, and terminability for the function.

Table 2: Decomposition of High-Level Function

| **Processes** | **Systems** | **Components/HAs** |
|---|---|---|
| -People detecting the fire and notifying others<br>-Fire response system notifying others of the fire | -volunteers who can detect the fire and notify others<br>-customers who can detect the fire and notify others<br>-fire alarm system | -Visual, auditory, or olfactory acknowledgement of smoke/fire<br>-Action of pulling the lever at a fire alarm pull station<br>-2 fire alarm pull stations<br>-4 flashing fire alarms<br>-3 auditory fire alarms |

Table 3: Conditions Indicating Need and Parameters Indicating Availability

| **Purpose** | **Conditions indicating that the function is needed** | **Parameters indicating that the function is available** |
|---|---|---|
| To ensure customer safety (safety function) | -One instance of a fire in the past<br>-Relatively small store so fire poses larger risk<br>-Volunteers and customers are generally elderly so greater precautions are needed | -Fire alarm system is tested on a regular basis and the indicators fulfill the NFPA standards<br>-Volunteers are aware of the locations of the fire alarm pull stations |

Table 4: Parameters indicating operation, success, and terminability

| **Parameters indicating that the function is operating** | **Parameters indicating that the function is achieving its purpose** | **Parameters indicating that the operation of the function can or should be terminated** |
|---|---|---|
| -The pull station automatically triggers | -A volunteer or customer was able to detect a fire | -The fire alarm station is tested so that when the pull lever is lowered |

| | | |
|---|---|---|
| the auditory and visual fire alarms<br>-Volunteers and customers are able to hear and see the indicators from any location in the store | -The volunteer or customer is able to pull the lever at the fire pull station and activate the fire alarm system<br>-The other volunteers and customers in the store react to and understand the meaning of the fire alarm system's activation | to its initial position, the fire alarms shut off<br>-A volunteer or customer misidentifies a fire or lies about a fire<br>-The auditory and visual indicators continue operating well after the fire has been put out |

## 3.2 Functional allocation

Most of the assessments regarding function allocation were made with engineering judgment. For example, the thrift store would neither need nor be able to afford an automated checkout station because of the store's small size and investing potential. Experiments or simulations could have supported the function allocations, but were not conducted due to limited supplies. Also, the information collected from the interviews and surveillance of tasks was enough to reveal the current function allocations and illustrate human limitations and human advantages that were accounted for in the optimal function allocations. The detailed results of the function allocation analysis are presented in the appendices. The function allocation for the function "Aid Customer at Checkout" is shown in Table 5.

Table 5: Function Allocation for the Routine Function "Aid Customer at Checkout"

| **Current allocation** | **Optimal allocation** |
|---|---|
| *Manual control:* Experienced and inexperienced volunteers are tasked with distributing merchandise and cleaning the store. They must display the merchandise in the correct sections, clean the floors, clean the bathroom and dressing room, and organize the merchandise so that the store is visually appealing | *Manual control:* The volunteers should continue to complete these tasks because they are not accompanied by serious consequences if performed incorrectly. In regards to distributing the merchandise in the store, a machine would be able to determine the appropriate section for the merchandise, but would not be able to display the merchandise in an attractive manner. In terms of cleaning the floors and the various rooms, a cleaning robot would be able to do a more thorough job than a human, but it would get in the way of customers and possibly annoy them. Thus, allocating the cleaning function to volunteers is a better option. Finally, the task of organizing the merchandise and clearing paths through the store should be allocated to humans because an inexpensive machine would not be able to handle fragile merchandise or organize it in an attractive way. |

## 3.3 Task analysis

Task analysis is performed for each high-level function. The task analysis template includes the following dimensions:

- Human Actions and Important Tasks
- Decision-making
- Response
- Teamwork and Communication
- Task Support
- Workplace Factors
- Factors Influencing Performance
- Hazard Identification
- Narrative of Activities
- Applicability
- Time Required
- Workload
- Number of Personnel Needed
- Knowledge and Abilities Needed

The number of personnel required to perform each task was generally assumed to be at least two. While most tasks are performed by only one person, some volunteers are unable to complete tasks such as bringing items into and out of the store and running the cash register due to physical and mental impairments. Thus, the "at least two personnel" requirement ensures that there is backup in case one of the personnel is unable to complete a task.

The tasks and relationships between tasks are displayed via a task diagram for each high-level function. The task diagrams are visual aids that guide the reader along the sequence of tasks. In a task diagram, each task is depicted in a box that is connected to one or more tasks with an arrow. A legend box in the bottom left corner of a task diagram indicates the meaning of each kind of arrow. The different arrows show various relationships between tasks:

- Shaded arrow: Linear relationship – (One task occurs directly after the other)
- Unshaded arrow: Conditional relationship – (The subsequent task may occur in some cases)
- Double arrow: Parallel relationship – (The two connected tasks occur concurrently)
- Solid stem: Single person – (The subsequent task is usually performed by a single person)
- Dotted stem: Coordinated effort – (The subsequent task is usually performed by

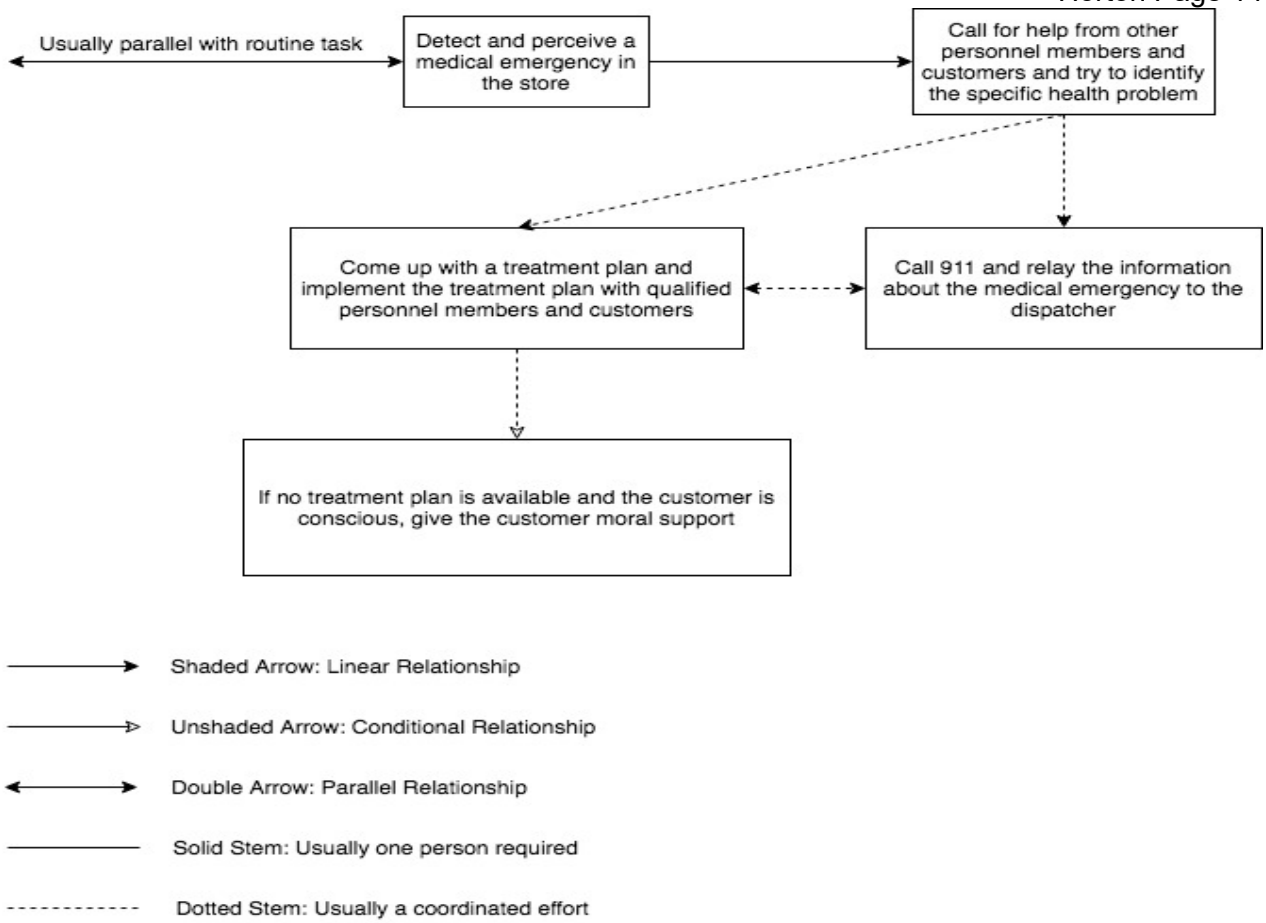
multiple people)

Figure 1 shows the task diagram for the function “Help Customer who is Having a Medical Emergency”. The function is achieved through five tasks:

- Task 1 – Detect and perceive a medical emergency in the store
- Task 2 – Call for help from other personnel members and customers and try to identify the specific health problem
- Task 3 – Come up with a treatment plan and implement the treatment plan with qualified personnel members and customers
- Task 4 – Call 911 and relay the information about the medical emergency to the dispatcher
- Task 5 – If no treatment plan is available and the customer is conscious, give the customer moral support

Task 2 follows task 1 sequentially and is typically performed by a single person. Tasks 3 and 4 follow task 2 sequentially, but are usually performed by multiple people. Tasks 3 and 4 can occur concurrently. Finally, task 5, which is usually performed by multiple people, could occur after task 3 if no treatment plan is available .

Figure 1: Task Diagram for the function “Help Customer who is Having a Medical Emergency”




For workload analysis, the interview questions were based on those used in the Subjective Workload Assessment Technique (SWAT) (Reid et al., 1988). SWAT assesses three workload factors: time pressure, mental effort, and psychological stress. The original scales of these factors in SWAT vary from each other. I converted them all to a 1-5 scale to quantify the cognitive workload. In the workload section for each task table in the appendices, an asterisk next to the cognitive workload measurement indicates that the cognitive workload for the given task was determined based on the manager's and volunteers' responses to the questions. If the cognitive workload measurement is not accompanied by an asterisk, then the measurement was determined based on my own responses to the same questions assessing cognitive workload.

To assess the time required for individual tasks, the average time it takes to perform a task was initially determined from personnel interviews and surveillance of tasks. After that, the worst case scenario for each task was identified and the appropriate time margin was added to the average time required for each task. A large enough time margin was used such that the estimated time required for a task would be greater than or equal to that for more than 99% of the task's variations. The determination of the average time required for each task bears uncertainties, but the large margins ensure that the time required for each task is generally adequate.

The task analysis for the safety functions and routine functions was conducted in a similar manner. The only differences were that the questionnaires were different for the safety functions and no surveillance of tasks was conducted for the safety functions because the safety functions address rare and sporadic emergencies. The detailed results of the task

analysis are documented in the appendices. Table 6 shows a subset of the task analysis results for the task "detecting and perceiving a medical emergency in the store." Table 6 reveals an important assumption that was made for some of the safety-related tasks. This assumption is that a customer can assume the role of a staff member when confronted by a crucial task, such as detecting and perceiving a medical emergency. Yet, this assumption may not be valid for some customers (such as customers who cannot speak English). Stores should evaluate this assumption and develop a reliable procedure for the relevant safety-related tasks if necessary.

Table 6: Subset of Task Analysis

| Task | Narrative of Activities | Applicability | Time Required |
|---|---|---|---|
| Detect and perceive a medical emergency in the store | First, a personnel member (or customer) detects a medical emergency by an auditory, olfactory, or visual cue. Then, this individual moves to the debilitated customer and analyzes the injury or health problem he or she is experiencing. | This task is imperative so that a customer's medical emergency can be addressed in a timely manner | 20 minutes (customer could pass out in bathroom or dressing room) |

## 3.4 Uncertainties in the analysis

Before the applicability of each analysis is assessed, the uncertainty that afflicted the analyses should be discussed. Various uncertainties were observed in the data collection for the FRA, FA, and task analysis. The purpose of this study was to determine the applicability of the FRA, FA, and Task Analysis in commercial retailing. Thus, high uncertainties in the analysis results impact the applicability of the analyses.

### 3.4.1 Uncertainty affecting every analysis

The first source of uncertainty that affects all three analyses is the completeness and reliability of data collected from the store volunteers. In a retail store, interviews can divert personnel members' focus and because personnel usually want to return to their tasks, they sometimes give answers that lack details and breadth. In the thrift store, many volunteers cannot spend much time away from their tasks in the store. These kinds of volunteers sometimes give abridged or heuristic answers to surveys or interviews.

The uncertainty can be observed during the interviews and analyzed by reviewing the data collected. For example, two cashiers were interviewed for the function "Aid Customer at Checkout" as they were working the cash register because there were no other cashiers available at the time. Both of these volunteers gave abridged and simple answers because they were not able to fully focus their attention on the interview. These simple answers are especially evident in regards to the questions assessing the factors that may impede various tasks. Out of 5 questions assessing these kinds of factors, volunteer 1 gave multiple examples

of factors for only one of the questions and volunteer 2 gave an example of a factor other than generic human error for only one of the questions (Appendix G, Section G-5). Also, when the personnel were solicited for an interview during a break or outside of store hours, they often gave the excuse that they were too busy or too tired to participate. Thus, the fact that many personnel in retail stores are either averse to or unable to focus their attention on interactive data collection techniques is a source of uncertainty in the analyses.

The next source of uncertainty that affects all three analyses is the very limited sample size in a retail store. In a retail store, there are rarely more than 20 personnel in the store at once and there are usually less than 100 overall. The limited availability of personnel means that the data collected may not represent the full spectrum of the information. For example, due to experience and military training, the manager of the thrift store often skewed the cognitive workload measurement because he gave low scores for tasks which would normally involve extreme cognitive effort and stress. When the manager and two volunteers were asked questions assessing their cognitive workload if they have to evacuate the store due to a fire, the manager's responses were very different than those of the volunteers. The manager's cognitive workload is 1.4/5 while the first volunteer's was 4.4/5 and the second volunteer's was 5/5 (Appendix B, Section B-5). Consequently, the manager's input greatly influences the average cognitive workload of 3.6/5 (Appendix B, Table B-9), which may not be representative of the overall population of store personnel and could be countered by more data.

### 3.4.2 Uncertainty affecting task analysis

Another major source of uncertainty is the variability of tasks performed in retail stores. This only introduces uncertainty to the task analysis because the steps and activities needed for each task depend on various factors in the store. The variability has an especially negative impact on the assessment of the time required to complete each task. For example, the time required to clean the store can take anywhere from a few minutes to 2 hours depending on the extent of the mess and the number of people in the store. This is evidenced by the manager's and volunteer 2's responses to the question "About how much time would it take you to clean or organize the store?" (Appendix F, Section F-5).

There are two major causes of the variability inherent in the tasks performed in retail stores. The first cause is the lack of procedures for most tasks in retail stores. In NPPs, the majority of tasks are performed according to well-validated procedures. However, in a retail store, the tasks that personnel must perform are always changing and are contingent on factors such as the time of year, the kinds of customers present, and the type of merchandise received. Because the tasks can be performed in many different ways due to these factors, they are adaptive. Thus, it is hard to determine the specific activities and requirements for each task. For example, the task "assisting a donor with carrying merchandise into the thrift store" is one of these adaptive tasks. The personnel member must develop and implement a plan to assist the donor, yet the plan and its implementation vary depending on the attitude of the donor, the characteristics of the donations, the number of personnel present, and other relevant

factors. As the response component for the task where a plan for bringing donations into the store is developed and implemented shows, the lack of a procedure and inherent variability in this task reduce the generalizability of the actions needed for every kind of response plan (Appendix E, Section E-4, Table E-6). Thus, the variability caused by myriad contingencies and the frequent lack of procedures impact the applicability of the task analysis in retail stores.

The second cause of the variability of tasks in retail stores is the predominant lack of automation. Retail stores primarily utilize human labor. In general, the function in retail stores that utilizes automation the most is checking out merchandise because of the presence of cash registers, credit card machines, and sometimes self-checkout machines. Other functions, however, are usually fully manual and require human actions for almost every task. For example, in the thrift store, five of the seven high-level functions identified are currently conducted with manual control (Appendices, Sections B-3, C-3, D-3, E-3, and F-3), which means no automation is used for the normal or hypothetical execution of the functions. Manual actions inherit more variability and are less predictable than actions performed by a machine. Therefore, it is difficult to predict or generalize the activities that a human will take to fulfill each task.

### 3.5 Applicability of Analyses

Overall, it was determined that the FRA could be applied to retail stores to a moderate extent. Two components, namely the purpose of each high-level function and conditions indicating that each high-level function is needed, were applied without any notable issues. However, the application of the rest of the components was made difficult by various sources of uncertainty (3.4.1) and disparities between retail stores and NPPs (4.1.1). Also, some components were excluded from the FRA (Table 1). Nevertheless, the majority of the requirements in the review criteria for the FRA in NUREG-0711 were completed for the high-level functions in the thrift store. Thus, although retail stores lack some key aspects that facilitate the application of FRAs in NPPs, FRAs can still be applied to retail stores to a moderate extent.

Next, based on the application of function allocations in the Capital Caring Thrift Store, it was determined that function allocations can be applied to retail stores to a great extent. It is true that the application of the function allocations in the thrift store was hindered by numerous disparities. For example, the requirements of the function allocation in NPPs that deal with modifications and operating experience were not included in the Thrift store analysis (Table 1), and various sources of uncertainty (3.4.1) and inflexibility (4.1.2) hampered the applicability of the function allocations. Nevertheless, in dealing with retail stores in their current state, the function allocations can be applied to a great extent. Even though most functions are performed by personnel and not machines, the function allocations can still be applied as evidenced by the allocations included in the appendices (Appendices, Sections A-3, B-3, C-3, D-3, E-3, F-3, and G-3). In addition, they can reveal important insights about the capabilities of the personnel and whether investing in automation in the future is a wise option.

The application of task analysis to the Capital Caring Thrift Store suggests that the analysis is applicable to retail stores to a great extent. Many components of task analysis

review criteria were incorporated into the analysis of the thrift store. Like the FRA and FA, the Task Analysis was hampered by various sources of uncertainty (3.4) and by various disparities between retail stores and NPPs (4.1.3). Despite these issues, however, the majority of the components in the task analysis could be sufficiently addressed. This is because the various data collection techniques provide sufficient information to discern the specific details of routine tasks and safety-related tasks. Even though some components, namely the workload and time required components, were subject to bias and subjectivity, they could still be assessed and can provide useful information when the efficiency of the store is judged.

# 4. Discussion

## 4.1 Characteristics of retail stores that are different from those in NPPs

NUREG-0711 was developed for reviewing human factors engineering in nuclear power plant design. Many differences exist between a retail store and NPP that may hinder the applicability of the FRA, FA, and Task Analysis in commercial retailing. Table 7 summarizes the characteristics of retail stores that afflict the applicability of each of the analyses. These characteristics are discussed with respect to the human factors analyses.

Table 7: Retail store characteristics which afflict the applicability of the human factors analyses

| FRA | FA | Task Analysis |
|---|---|---|
| ● A shortage of automated indicators of the parameters for most functions<br>● Most high-level functions are very simple and do not need to be decomposed | ● Very limited financial resources<br>● The routine functions are simple and require low levels of expertise | ● Many workers are not re-trained on how to complete their tasks and some are completely unaware of written procedures<br>● New, unforeseen tasks are always presenting themselves to the store personnel and the order of tasks is variable |

### 4.1.1 Retail store characteristics which afflict the Functional Requirements Analysis

For the FRA, one significant impediment that a retail store poses is that for many of the functions, there are no automated indicators to indicate the status of a function, e.g., whether a function is available, is operating correctly, has achieved its purpose, or can or should be terminated. In a NPP, there are many automated function indicators for operators to assess plant status. In a retail store, however, there are very few functions where automated indicators of parameters indicating availability, successful operation, completion, or terminability exist. The problems associated with the lack of automated indicators are evident with the function “Identify and Respond to a Robbery”. For example, the parameter wherein the personnel member calls 911 and conveys all relevant information cannot be measured easily because there are no automated cues that indicate its presence (Appendix D, Section D-2, Table D-3). For the parameters that indicate that the high-level function can or should be terminated, the parameter where the police and other personnel can be notified if the robbery was a false alarm was also hindered by a lack of automated indicators (Appendix D, Section D-2, Table D-3). As a result of this shortage of automated indicators, there is no structured way to confirm that the aforementioned considerations have been fulfilled, and this makes it more difficult to both identify the high-level functions and determine the requirements for their success.

Another significant aspect of retail stores that makes it hard to apply the FRA is that, unlike in a NPP, the high-level functions in retail stores are very simple. This simplicity makes it unnecessary to decompose the functions into their respective processes, systems, components, and human actions. For example, the function “Receiving and Pricing Merchandise” (Appendix E, Section E-2, Table E-1) does not involve systems that can be decomposed effectively.

The only remaining analysis components of the FRA are the purpose of each high-level function and conditions indicating that each high-level function is needed. Collecting the information needed for these components is straightforward.

### 4.1.2 Retail store characteristics which afflict Function Allocation

The function allocation analysis was mostly successful but experienced some issues in terms of its applicability in retail stores. The first issue dealt with the financial resources that a retail store has. While NPPs determine functional allocation based on many factors, retail stores are largely limited in functional allocation by their financial resources. The analysis shows that even when the tasks of a function would be performed more efficiently and precisely by a machine than by a person, the function is usually allocated to the person because of the limited financial capabilities of the store. For example, functions such as “Receiving and Pricing Merchandise” have to be allocated to personnel because the store would not be able to afford the necessary machinery for automation (Appendix E, Section E-3). As this example shows, retail stores’ limited financial resources hinder the application of flexible function allocations.

Function allocation analysis is useful in determining the allocation of safety functions because they are generally more complex and come with more serious consequences if they are performed incorrectly. On the other hand, the routine functions in retail stores are much simpler and less problematic if performed incorrectly than those in NPPs. This fact makes the function allocation less meaningful because it would be more effective to allocate the routine functions to humans than to machines. This is because most personnel would have no problems with performing the accompanying tasks and there are very few significant consequences if the personnel perform a routine function in the retail store incorrectly. For example, the consequences of distributing items in the store and cleaning the store incorrectly are not detrimental enough to warrant automation. This was one of the reasons why manual control was determined to be the optimal function allocation for this high-level function (Appendix F, Section F-3).

### 4.1.3 Retail store characteristics which afflict Task Analysis

As for the task analysis, many of the components in the NUREG-0711 review criteria could be applied to retail stores to a great extent. The time required and task response components were the most troubling due to the uncertainty discussed in Section 4.3, yet they could still be applied to the thrift store as baseline assessments. In addition, some of the components incorporated into the study had inapplicable aspects. For example, no tasks in the store require special and protective clothing, which is an aspect of the task support component. Thus, this aspect was inapplicable but the other aspects of the task support component could be applied to

the store's tasks.

One important difference between retail stores and NPPs is that many workers in retail stores are not re-trained on how to complete their tasks and some are completely unaware of written procedures for how to complete their tasks. The lack of recurrent training poses a major impediment to task analysis. Untrained personnel are more likely to give information regarding action sequences that do not accurately reflect the procedures for tasks with established plans. For example, despite the presence of a written fire response plan that requires that all personnel know the locations of the fire extinguishers, the two volunteers interviewed for the fire response function were unaware of the locations of the extinguishers (Appendix B, Section B-5). Because of their ignorance of the locations of the extinguishers, the two volunteers did not relay needed information about the procedure for using the fire extinguishers. This hindered the process of determining the activities needed for the task where the fire extinguishers are used to put out the fire (Appendix B, Section B-4, Table B-6). As this shows, a lack of training and a lack of knowledge regarding established procedures on behalf of store personnel hampers the successful application of task analysis in retail stores.

Another important difference between retail stores and NPPs is that task sequences for a function are more difficult to determine in retail stores than in NPPs. This is partly due to the fact that retail stores sometimes lack procedures like NPPs have. IT is also due to the fact that there are many uncontrollable factors in retail stores that can cause tasks to become reordered. This applies to both routine tasks and safety-related tasks. For example, the safety-related task where a fire extinguisher should be used to put out a fire if it is small could easily occur before the evacuation of the store is conducted. If the fire is small enough and is close enough to a personnel member who knows where the fire extinguishers are and how to operate them, the personnel member will likely choose to extinguish the fire before triggering the fire alarms. However, the task of extinguishing the fire was ordered after the task of evacuating the store in the task analysis (Appendix B, Section B-1) because it was assumed that most personnel do not know the locations of the fire extinguishers or do not know how to operate them. This kind of reordering can occur for most of the high-level functions and is thus an impediment to the successful application of task analyses in retail stores.

Finally, another distinction between retail stores and NPPs that makes it harder to implement task analyses in retail stores is that new, unforeseen tasks are always presenting themselves to the store personnel. For example, the cashier in the thrift store follows a written plan regarding how to conduct the checkout process. However, the cashier often has to diverge from this plan when confronted by unique customers. One group of customers that the plan could not account for are native Afghani customers. There have been a few occasions in the past where Afghani customers have attempted to bargain down the price of an item they wanted to buy because, in their culture, bargaining is a typical aspect of purchasing merchandise. In this case, the cashier has to assume the new task of explaining that prices are set and are irrefutable to the Afghani customers. This problem afflicts safety functions in addition to routine functions because the personnel in retail stores are often untrained in how to effectively respond to an emergency. This lack of training can cause them to assume tasks that the emergency response procedures do not call for. However, these new tasks can actually facilitate the completion of safety functions because they can sometimes be more adaptive and flexible than those found in an emergency response procedure. Nevertheless, the assumption of new tasks in retails stores hampers the applicability of task analyses because it is impractical to account for every potential task in the task analysis.

## 4.2 Summary of lessons learned from the analysis and recommendations

The implementation of the analyses in the retail store has revealed useful insights for managing a retail store.

First, the functional requirements analysis is particularly useful for developing the framework for the store's operation and for delineating the specific kinds of human actions, tools, and indicators needed. Defining the high-level functions can prove especially useful for retail stores because doing so can lead to increased focus on efficiency. Yet, this is a fairly time-consuming analysis because of the data collection required to ascertain the specific details of each high-level function.

Next, the function allocation analysis is a quick analysis that requires little data. It can be applied to both routine and safety functions, and is particularly useful for task delegation because it can be used to choose between automation and human labor for the high-level functions. These factors make it the most practical analysis out of the three because it is not time-consuming and conducting function allocations facilitates the process of weighing the advantages and disadvantages of humans versus machines before an investment is made.

Finally, the task analysis is very time-consuming due to the sheer number of components that need to be completed. It requires significant data collection so that the specific aspects of each task can be ascertained. Also, the task analysis is difficult to apply to safety-related tasks because of their unpredictability. In addition, it is impractical to apply the task analysis to routine tasks because most are so simple that it is not effective to analyze them to the extent required by the task analysis. Thus, the task analysis is the most impractical analysis out of the three.

## 4.3 Limitations of the study

The applicability of these analyses was partly subjective and was based on the setbacks and successes experienced during the application of the analyses. Also, the Capital Caring Thrift Store was not the best model to use for this study, but was most accessible in terms of data collection. However, unlike in the average retail store, the personnel in the thrift store are unpaid. This may have led to additional uncertainty because the personnel in the thrift store do not have to complete their tasks with as much diligence as paid personnel in a typical retail store. Also, paid personnel are probably more knowledgeable when it comes to completing tasks in an effective manner, and a lack of this knowledge may have led to an overestimation of components such as the time required and the quantity of actions required for each task. In addition, the thrift store was experiencing a shortage of personnel during the weeks of data collection because many personnel were on vacation. This shortage may introduce biases in the results because some of the personnel gave responses that skewed the results in components such as the cognitive workload assessment.

## 4.4 Insights on further research

If this project were repeated, improvements can be made to yield more accurate results and reveal more about the use of human factors analyses in retail stores.

- Use a larger retail store such as Macy's or Walmart for the FRA, FA, and task analysis so that the applicability of these analyses can be assessed on a larger, more realistic scale.

- Increase the number of personnel interviewed. In order to identify a trend or pattern in the responses, more personnel would have to be interviewed.

- Spend more time on the surveillance of tasks. If more time is devoted to surveilling tasks and determining the time it takes to complete each task, more data could be collected for the time required to complete the tasks and the data can be used to improve store efficiency.

- Reassess the analysis components. While it would be difficult and time-consuming to include more components in the analyses, doing so could lead to important realizations that the currently incorporated components did not procure. Also, some of the excluded components could be applicable to larger retailers such as Walmart.

Finally, the project could be expanded to assess the effect of the store's use of the analyses on efficiency. Many industries have been using the results of FRA, FA, and task analysis to improve task assignment, staffing, procedures, personnel training, and human-system interface design, which ultimately improve efficiency and enhance safety. An expanded study can test the efficiency in terms of profits gained; the store's daily profits could be tracked before and after the routine functions and routine tasks are changed to account for the results of the FRA, FA, and task analysis. To test the effectiveness of ensuring customer safety, mock emergencies could be conducted to test the store's level of response before and after the safety functions and safety-related tasks are changed to account for the results of the FRA, FA, and task analysis.

## 5. Conclusion

The results of applying human factors analyses to a thrift store demonstrate the applicability of functional requirement analysis, functional allocation analysis, and task analysis to retail stores. Overall, the results demonstrate that the function allocation and task analysis portions of the NRC's HFE model can be applied to retail stores to a great extent, and the functional requirements analysis can only be applied to a moderate extent. Even though it would probably be more useful to a store manager to know the practicality of implementing these analyses, the applicability of the analyses can help managers determine whether it would be pragmatic to apply the analyses in their stores.

The applicability of these analyses is exciting because it means that human factors analyses could be implemented if the analyses are structured to account for the specific characteristics of retail stores. Through the use of human factors analyses to improve task assignment, staffing, procedures, training, and store ergonomics design, the retail industry can advance toward the goals of maximizing profits and ensuring customer safety.

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