AEEM 6099 Systems Engineering & Analysis

Shopping Assistant System

Main Project - Milestone 3

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1. Project Description

This project proposes a shopping assistant system aiming to help international tourists achieve a better shopping experience in big malls like Super Brand Mall (SBM) Shanghai. A mobile system integrating with information service will be developed for assisting the international tourists to do shopping in big malls. Thus, the system will be able to provide convenience to international tourists and save their time on a tight shopping schedule.

2. Evaluation during Project Phases

Evaluation is accomplished in each of the phases shown in table below:

Phase	Evaluation Type	Evaluation
Conceptual Design	System Level Evaluation • Type 0 Testing	In our design of shopping assistant system, this phase is very important since we need to use the analytical model to get the device performance and the various top-level models needed to have simulation of the shopping car device are as follows: 1. 3-D model of the shopping cart (size, material, surface, weight) 2. Cart moving simulation (velocity, driving power and torque calculation) 3. Cart payload simulation 4. Information processing simulation (interaction time) 5. Total Cost
Preliminary Design	Subsystem Level Evaluation (Engineering Models) • Type 1 Testing	The sub-system levels evaluation comprises of taking input from the results of system level analyses and applying those inputs to the sub-systems in the form of both tests and analysis. For our design project: shopping assistant system, in this phase, the tests we should consider are: 1. Mock-up models of the shopping cart to see which design provides better lightweight and required size. 2. Test model for checking the cart velocity. 3. Material testing model to see the payload of cart. 4. Mock-up testing model for checking the interaction time of touchable screen.
Detail Design	Component	In this phase testing, it includes performance tests,

& Development	Level Evaluation (Prototype Models) • Type 2 Testing	environment qualification, structure tests, reliability qualification, maintainability demonstration, support equipment compatibility tests, personnel test and evaluation, technical data verification, software verification and supply chain element compatibility tests. For our project, it corresponds to the testing to be conducted on actual hardware and software to meet the design equipment requirements: 1. Performance tests - Here the individual models are tested separately to ensure that each model is functioning as per design. We should test whether the diving controller and driver give the required output. 2. Structure tests – Materials here are to be used for the shopping cart body and surface and we need to check the size and weight to meet the requirements. We also need to test the material whether they can sustain damage when fall down. There are various materials considered and each are tested to yield the best fit material. 3. Reliability qualification – We need to test the lifecycle of our system's equipment including the battery lifespan, touchable screen's usability. 4. Maintainability demonstration – Mock models are used to demonstrate how maintenance can take place. 5. Personnel Test and Evaluation – Various level of personnel training, test and evaluation involved are people who will handle the cart device maintenance, people who will work in big market to ensure the cart device being the

		right place. 6. Technical data verification – the testing model should give the output of driver, information processing and cart payload. 7. Software Verification – Software testing at the touchable screen should be checked to see the proper functional using as the device can translation, information searching and navigation. 8. Security – In this case, our system need test to check the information security of end-users.
Production & Construction	Test and Evaluation (Production Models) • Type 3 Testing	At this level, testing is conducted through a series of simulated operational exercises. This is basically a "practice test" to use a person who are trained operating our shopping assistant device and our design engineers will perform the tests. Various level of testing like the information processing time, cart moving velocity, cart payload and fully-functional using time are collected and examined by user and design engineers to look for anomalies in modeling, designing and so on.

Operational Use and System Support	Test and Evaluation (Operational Model) • Type 4 Testing	During this phase, formal testing will be accomplished in conjunction with the incorporation of technology enhancements and system upgrades to ensure that the appropriate measures of effectiveness are being maintained as system operation continue. Once our shopping assistant device is in operation, the performance like efficiency and fully-functional using condition will be assessed and the data & information will be collected and analyzed by the user and design engineer to evaluate actual performance versus expected performance.

3. System Test and Evaluation Plan

The test report shall include at a minimum, photographs of the test set-up, any deviations and failure information, corrective actions if any, detailed data as required, test data sheets and

results. And test and evaluation plan should include：

3.1 Identification of all the tests to be accomplished, the items to be evaluated, the schedule of each, required inputs and expected outputs

Our tests shall be carried out on the component of our design system. These tests shall be conducted by software and hardware manufacturers which includes:

- Cart device performance test – in this category, the various sub-modules are integrated and tested for getting the whole cart device performance to see whether it meets the requirement. In our project, we need to simulate the cart device model and test the performance of cart device.

- Information processing test – information searching and showing up need searching, transferring time and it should be within 2 seconds which meet our requirement.
- Maintenance test – we should check the charging time of the cart device and whether the battery could support 8 hours' fully-functional using of users.
- Security test – to ensure customers' information safe, it is important to make the system information security as it involves end-users' pay information and this aspect can be checked by using qualified personnel to try and hack the software system in different ways possible and test the ability of the software to resist such attacks.

3.2 Identification of the organization responsible for the administration

Since this project is created by our company, our company is responsible for providing a technical design of the shopping assistant device that meets all the user requirements and then these design specifications are sent to the manufactures who will provide the actual physical system and software providers. After the design phase, the shopping assistant cart will be sent to big shopping mall to test the product performance.

3.3 A description of the test location, local political factors and environment

- Test location - All these tests location should be company's test facility and personal used will be trained technicians. After the test within company, it should be tested and evaluation within the big mall once the products be set and used by users. We also need to collect and analyze the information and data for future improvement.
- Local political factors/ social factors – Since our tests are all performed within our company facilities, and only trained personnel test it, there may not be serious social concerns and local political concerns.
- Logistics provisions – the major stress test is performed on the shopping assistant cart's equipment, maintenance and hardware including hardware like WIFI/Bluetooth, battery and touchable screen. As the amount of our device is not huge, it may be no serious concerns about the logistics provision.

- Test environment – All the test environments for the shopping assistant device are indoor in the company with simulated conditions.

3.4 A description of the test preparation phase of each category of testing as required

In the section of TEMP, we list down the specifications of the various tests' preparation:

- In every test, we need make documents with detailed instructions which have to be followed by the conducting personnel.
- The training of test and supporting personnel – in every test, some experienced are involve to ensure transfer knowledge and prevention of any technology error.

3.5 A description of the formal test phase

- Software requirements – Many tests require software control to perform the tests. The
    - particular software required and the expected input and output of the software are
    - documented in this part.
- Data collection - During the test and evaluation, we should record the information of each test's output like the information processing time, total cost of device, size and weight of the shopping cart, MTBF and cart moving speed to get the average value for the whole testing models.
- Test reporting - Every test performed has to be documented in prescribed format.
- The test has to be described in detail and the expected and actual outputs are also
- documented in the TEMP for future references.

3.6 A plan and associated provisions for retesting

Retesting may happen because sometimes the tests performed may not yield expected results. This always does not mean that the models or designs are wrong and everything has to be re-worked. If the desired and actual outputs from a test are different, then we need to know three things and based on their answers necessary action are taken: why did the test fail? How was the test plan validated? And is there any different way that the test can be performed? Suppose the information processing time test failed as

sometimes it use over 2 seconds, it does not mean the model is wrong, it may because the internet connection missing or WIFI problem that we can just change to a different place to test.

3.7 A description of the final test report

The entire test report based on all the tests and the test results are complied into the final report based on the format specified by the users which in this case the trained users and the report is handed over to the person that organized our design team in our company and give to big mall who has interest to get our shopping assistant device. Then we can get feedback from the big shopping mall and based on the feedback, corrective action can offer if needed.

4. Decision Situations

4.1 Decision evaluation with controllable and uncontrollable variables

Decision evaluation is an important part of systems engineering and analysis, Evaluation is needed as a basis for choosing among the alternatives that arise during the activities of system design, as well as optimizing systems already in operation. In either case, equivalence provides the common evaluation measure on which choice can be based.

Decision evaluation often requires a combination of both money flow modeling and economic optimization approaches. When investment cost, periodic costs, or project life is a function of one or more decision variables, it is important to optimize over these variables as a prerequisite to the determination of economic equivalence. This optimization is linked to a decision evaluation through one or more money flows, which, in turn, are used in calculating a measure of economic equivalence. Optimization requires that an evaluation measure be derived from an economic optimization model.

An economic optimization function is a mathematical model formally linking an evaluation measure, E, with controllable decision variables, X, and system parameters, Y, which cannot be directly controlled by the decision maker. It provides a means for testing decision variables in the presence of system parameters. This test is an indirect

experiment performed mathematically, which results in an optimized value for E. The functional relationship, in its unconstrained form, may be expressed as

$$E = f(X, Y)$$

In our project, the cart device design is one of the equipment requires decision evaluation. Our decision is to choose a cost efficiency design which meet the operational requirement. The evaluation measure E in this case is the cost of each cart. The output of the evaluation function is to minimize the cost of the design.

The controllable variables X in this case are:

- Material to build the cart device.
- Total weight of the cart device.
- The size of the cart device.
- The payload of the cart device.

The system parameters Y which cannot be controlled by the decision makers are:

- Cost of the material used in the cart device.
- The total material wasted in the cart manufacturing.
- Labor rates, manufacturing and support costs.
- Material production and transportation cost.
- Turn-around time between design submission and actual production.

4.2 Multi-Criteria decision situation

In a real world, a decision must made in the face of multiple criteria that jointly influence the relative desirability of alternatives under consideration. The decision should be made only after considering all relevant criteria, recognizing that some are quantifiable, and others are only qualitative in nature.

In our project, one of the multi-criteria decision situations is to choose the indoor real-time location technology among the wireless network technologies. The objective is to select the best technology which cover most of the operational requirements and is cost efficiency. There are several factors that are involving in making this choice and the most important factors are listed as follows:

- Speed – as for tracing the cart device and tablet computer, the speed of data transmission needs to be evaluated. The real-time data transmission will be a important factor to the user experience.

- Accuracy – accuracy is an important factor of indoor location technology in terms of user experience. In order to give the best experience to the end-user, the accuracy of each technology will be evaluated.
- Transmission Range – as the user will do shopping in the mall which is a big place, the data transmission range of wireless connection technology should be evaluated, once the distance between cart device and tablet computer reaches the maximum of data transmission range, the system will be not robust. So we need to select the technology with appropriate data transmission range which will cover the most user scenarios.
- Power consumption – As the equipment carry a rechargeable battery and is required to be perform at least 12 hours per day, the power consumption of this indoor location should consume less power.
- Cost – as the cost varies in different option of adopting different technologies, we need to evaluate the each set of devices used in each cart and come up with a total cost for the technology we choose given by an estimated quantity of equipment we are going to distribute.

4.3 Evaluation matrix and Evaluation vector for a hypothetical design situation

A decision evaluation matrix is a formal way of exhibiting the interaction of a finite set of alternatives and a finite set of possible futures. The general decision evaluation matrix is a model depicting the positive and negative results that may occur for each alternative under each possible weight.

In our project, the selection of indoor location technology (wireless connection technology) has an important impact on the system mission parameters (in order to meet the operational requirement of tacking the cart device and tablet computer) and overall system configuration.

Given two alternatives in the market, Wi-Fi and BLE, the sample analysis is listed below.

- Alternatives
  - Wi-Fi – Wi-Fi uses radio waves (RF) to allow two devices to communicate with one another. The technology is most commonly used to connected Internet routes to devices like computers, tablets and phones; however, it can be used to connect together any two hardware components. Wi-Fi is a local wireless network that run

of the 802.11 standards set forth by the Institute of Electrical and Electronics Engineers (IEEE). Wi-Fi can utilize both the global 2.4 GHz UHF and 5GHz SHF ISM radio bands. The Wi-Fi Alliance certifies some products, allowing them to be labeled as "Wi-Fi Certified." In order to receive that designation, and product must go through the Alliance's interoperability Certification testing.

- BLE – Bluetooth and Bluetooth Low Energy are wireless technologies used to transfer data over short distances. The technology is frequently used in small consider devices that connect to user's phones and tablets. For instance, the technology is used in many speaker systems. Bluetooth Low Energy uses less power than standard Bluetooth and is used in hardware such as fitness trackers, smart watches and other connected devices in order to wirelessly transmit data without heavily compromising the battery power in a user's phone.

- Factors

There are many factors compared between BLE and WIFI, the major factors will be considered in our project are listed as below

- Speed
- Accuracy
- Transmission Range
- Power Consumption
- Deployment Costs

- The weights for each factor are
  - Speed – 10%
  - Accuracy – 30%
  - Transmission Range – 10%
  - Power Consumption – 20%
  - Deployment Costs – 30%

Each factor is rated from 1 to 10 with 1 being least favorable and 10 being highly favorable.

Alternative	Speed (10%)	Accuracy (30%)	Transmission Range (10%)	Power Consumption (20%)	Deployment Cost (30%)	Weighted Total
BLE	6	8	8	9	8	8

WIFI	10	6	8	4	5	5.9

Based on the above decision evaluation matrix, the alternative that is the best choice for indoor location technology is BLE.

- BLE – BLE is more suitable for transmitting small amounts of data at 1 Mbps, BLE is not suited for sending data in real-time to a server. If real-time data is required, a special gateway must be used to send the data. When positioned indoors, BLE use advertisement packets to provide additional information. There is a unique UID number that can be read by other Bluetooth receivers. Location accuracy can be ensured this way. Transmission Range varies depending on the Bluetooth product that you use. The transmission range varies from 50 feet to 1500 feet. Bluetooth devices have lower power consumption. BLE are less costly, self-sufficient and can run on a single battery for over 2 years depending on usage. No configuration is required.
- Wi-Fi – The Wi-Fi can transmit at a speed of up t0 1.3 Gps, so it is ideal for bigger files and data. Wi-Fi direct provides maximum data transfer speed, about 10 times more than what you get with Bluetooth Classic, but BLE is about 20-30 times slower than Wi-Fi Direct. Wi-Fi is a wireless Local Area Network technology where two or more electronic devices use the ISM radio band to communicate. WIFI technology hence does not rely solely on the proximity of the user. Wi-Fi has a transmission range that's limited by the frequency, transmission power. Typically, the range could reach 160 ft indoor. Wi-Fi requires 10 times more power than BLE. Wi-Fi needs router configurations and they have to be connected to a power source, the expense also depends on the router used and of course the manufacturer.

Consider the decision making under certainty, the factor that will be considered is accuracy since it has the highest weight and is certain to matter the most.

Alternative	Accuracy (100%)
BLE	8
WIFI	6

4.4 Illustration of paired outcome

In our project, we need to design all the components so that we need to do a number of trade studies in order to confirm the criteria defined are optimal for our system. Take battery and indoor location technology as an example for paired outcomes evaluation.

We take power consumption of indoor location technology and the battery energy and cost for the trade study as listed below.

- Batteries
  - Nickel Cadmium:
    a. Gravimetric Energy Density (Wh/kg) – 60
    b. Cost - $50
  - Lithium Ion:
    a. Gravimetric Energy Density (Wh/kg) – 140
    b. Cost - $100
- Indoor location technology
  - BLE:
    a. Average Energy consumption / 24 hours a day – 0.6 watts
  - Wi-Fi
    a. Average Energy consumption / 24 hours a day - 6 watts

The paired outcome evaluation matrix is as below:

	Typical Value				
	Poor	Below-Average	Average	Above-Average	Excellent
Battery GED (wh/kg)	50	80	100	120	160
Battery Cost ($)	100	80	60	40	20
Energy Consumption (watt)	10	7	5	3	1

Considering the potential result from the above trade studies, the following design configurations are possible:

	Configuration Alternatives			
	NiCd+BLE	NiCd + WIFI	Li-ion + BLE	Li-ion + WIFI
Battery GED	Average	Average	Excellent	Excellent
Battery Cost	Above-	Above-	Poor	Poor

	Average	Average		
Energy Consumption	Excellent	Below-Average	Excellent	Below-Average

Based on above paired outcomes, we can find that the configuration with Li-ion and BLE is the best choice among the four configurations. As the following standards are defined:

- Battery Energy Density: Excellent
- Battery Cost: Poor
- Energy Consumption: Excellent

5. System Data Collection and Evaluation

5.1 Cost-effectiveness

Cost effectiveness of a system depends on the system effectiveness, operational availability, producibility, dependability, supportability, sustainability, the total life cost to name a few.

5.2 System-effectiveness

The data required to measure these parameters are generated from the mathematical models and 3-D models and the simulated tests performed on them. For example, in order to system effectiveness we have to provide data on the material efficiency of cart device design and manufacturing, the accuracy of indoor location system and etc. Dependability of the system depends on the amount of unscheduled maintenance that the system needed during its operational life cycle.

5.3 Operation Availability

This parameter is dependent on the actual amount of equipment we deployed in the mall, the battery lifecycle and recharge time, as well as daily maintenance and customer usage. We need these data to evaluate the operational availability to maintain this parameter at an appropriate value.

5.4 Lifecycle Cost

The total life cycle cost is dependent on the cost of the software development, the hardware deployment, support and maintenance and repair and recycle, as well as the personnel training cost. All these data are needed for evaluate cost-effectiveness.

5.5 Reliability

We need the data of system failure and failure rate, and the actual cause of the failure including the software failure, hardware failure, user maloperation frequency. With these data, we are able to find the root cause and improve the reliability through redesigning, repairing or replacing the component unit.

6. Reference

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