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To: MECH 3200 – 12S Students
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Subject: HW Chap.1,2,3 Solution
Reference: [1] HW Chap.1,2,3 Assignment

Ref.[1] describes a design problem involving the Alaska State Parks Department's interest in providing recreation hiking access to the Grewingk Glacier Trail from a trailhead on the south shore of Kachemak Bay. The trail crosses the glacier outflow creek. The outflow water volume has grown in recent years as glacier melting has increased, making the ford through this creek untenable at most times of the year. Parks favors a creek crossing based on tram car suspension from an overhead cable, with propulsion provided by the hikers. Their experience shows this to be a reasonable means for allowing hiker access, limiting non-hiker access, and enabling easy installation and maintenance.

Ref.[1] asks for the development of:

1. Customers
2. Customer Requirements
3. Engineering Characteristics
4. Engineering Characteristic target levels (enabled by a House of Quality)
5. Engineering Design Specification
6. Essential Problem Statement

These items are developed in the following sections.

Customers

Direct users are the hikers. Hikers might be either crew (capable of propelling the tram car) or passengers (incapable of propulsion, such as dogs, children, elderly, injured). Hikers might bring overnight camping gear or mountain bikes. A composite customer called 'hiker' is specified.

Indirect users are installers, maintainers, Parks (owner/purchaser), and society (apart from those crossing the creek). The latter two stand for the people of Alaska, who must ultimately pay for the tram and live with it. Since the tram site is remote, and the product type (overhead cable) enables installation with low environmental impact, society's non-fiscal requirements can be considered by checking at the end of the design process (rather than through consideration as a front-end customer). Parks is specified as a composite customer incorporating the owner, installer, and maintainer functions.

Customers:

- Hikers (crew and passengers, with backpacks and bicycles)
- Parks Dept. (purchaser, installer, maintainer)

Customer Requirements

The hikers want their party to cross the creek, with gear, in safety, and with low interference in their hiking progress. Propulsion effort is important. Safety has both actual (functional) and virtual (perceptual) aspects. Some hikers may want to play with the tram (sight-see, fish, hooliganism), though Parks would like to discourage this.

The crossing operating profile involves:

- Discovery (how to use the device)
- Retrieval (inevitably, the tram car will be left on the wrong side of the creek)
- Ingress (get in and stow gear)
- Propulsion (drag cart along cable)
- Egress (get out)

Form is largely governed by capacity. Capacity should be sufficient to transport a hiking party, without impairing propulsion. Hiking parties can be of a variety of sizes and compositions, with different ratios of crew to passengers, although larger parties can cross in multiple trips. A party of one (crew) should be feasible. Some passengers may cross alone (children, elderly), while others will require escort (pets, injured, unruly children).

Parks is concerned with initial cost, cost of ownership, and hiker satisfaction. Initial cost includes the difficulty of the installation on-site – labor hours plus transport of loads to the site. Installation calendar time is less important. Cost of ownership and hiker satisfaction are both impacted by reliability and robustness.

Customer Requirements:

- Easy to learn to use
- Retrievable from opposite bank, empty or with passenger
- Crew can propel crossing for entire hiking party
- Crew and passengers are safe from falling
- Lateral motions are not alarming
- Materials and installation tools transportable by HMMWV
- Cost a small fraction of Parks foot bridges for similar spans

These are correlated by importance to each customer in the following section. These requirements are ‘musts’. ‘Shoulds’ are included in the Engineering Design Specification.

Engineering Characteristics

Easy To Learn is subjective, but could be quantified by number of words printed on instruction signposts, as long as the instruction passages are blind-judged for feasibility. Might examine Design Methodology literature to find other useful approaches for measuring 'easy to learn'.

Retrievability can be covered under the ability to cross the hiking party, as long as the operating profile includes retrieval.

Hiking party propulsion addresses the main function of transporting hikers across the creek. Time for whole-party propulsion measures both crossing feasibility (capacity, propulsibility) and crossing performance. Measurement of crossing time for the whole party combines crossing time per trip with relative capacity (load per trip). However, crossing time results will vary with: party size; crew strength and endurance; and the ratio of passengers to crew in the party. The ratio of un-escorted to escorted passengers and the weight/volume of equipment per person also effect crossing time assessment. To create a measureable engineering characteristic, without delaying the design process to perform customer characterization studies, two representative hiking parties are defined:

- One hiker (50th percentile strength/weight (combined M/F)), overnight pack
- Four hikers, two crew (one at 50th percentile, one at 5th percentile), passengers require escort, day packs

Assessment of the concepts generated from these EC's will have to consider that the party definition is approximate. The Engineering Design Specification will include suitability for dogs and bicycles.

Safety from falling can never be assured, but falling can be made difficult. As a metric, the energy necessary for a crew or passenger to depart the tram car may be estimated (energy to raise a body over a rail; energy to break a safety strap). Body characteristics are again important, and so a child (50% weight/height (M/F) 6 year old) is chosen as an EC. Concept assessment will have to consider adult falling as well.

Discomfort and fear related to tram car dynamics are mostly related to accelerations in the plane normal to the cable (rolling, heaving/swaying), although yawing and pitching can also be upsetting. The magnitude of these motions depends upon the forcing (wind loads, dynamics in response to shifting crew or passengers), but for a given load, these will scale inversely with the periods in heave (mass on a taught cable) and roll (tram car as pendulum). Yaw and pitch can be easily inhibited by suspending the tram car (rigidly) from two points on the cable.

Transportation of materials and tools to the site for installation can only be accomplished by HMMWV or equivalently capable off-road vehicle (of which, the HMMWV is most readily

available). All feasible designs will be decomposable into HMMWV loads. The number of loads is a useful measure of installation time and expense.

Exact performance can usually be met at high cost, and so this is constrained by making low cost an EC. The overall projected cost should confirm Parks' vision that the human-powered tram car will be a low cost solution. Manufacturing cost is a useful engineering characteristic to measure this.

Existing Alternatives

Existing alternatives to developing a product include actions such as hiking to the nearest passable ford, or building a more substantial structure such as a footbridge. However, Parks has already made the decision to develop a human-powered tram. Parks has some experience with similar products, and so the present design problem may be compared to:

- Hand Tram at Winner Creek/Girdwood, AK
- Skybike at plasmacam.com
- Rope Ferry at River Fulda, Germany

House of Quality

A Quality Function Deployment Matrix (Fig.1) relates the Customer Requirements to the Engineering Characteristics and determines EC target levels.

Notes:

- Safe from falling is rated lower because of the undesirability of extreme containment
- Not apparent that Skybike has a retrieval mechanism – one like Rope Ferry's added to alternative concept
- Skybike not suitable for un-escorted passengers
- Crossing times are longer if instructions take more time
- Crossing times are shorter with less car mass, hence less containment
- Tight cable reduces propulsive effort, but increases undesirability of bounce motion
- More HMMWV loads should mean more material

Engineering Design Specification

Performance

- Must
 - Cross creek 150 ft. between banks
 - Sufficient instructions in between 200 and 300 words
 - Single hiker can retrieve and cross in between 450 and 600 s.
 - Family can retrieve and cross in between 600 and 900 s.

Capacity

- Must
 - Accommodate 1 bicycle per person
 - Accommodate 1 overnight pack per person
 - Safely accommodate dogs (of worth-while size)
- Should
 - Easy Ingress/egress
 - Unsuitable for horse
 - Unsuitable for dirt bike

Reliability

- Should
 - High availability with only limited, annual maintenance
 - Robust to possible abuse and extreme weather

Safety and comfort

- Must
 - Energy to enable a child's fall between 150 and 300 N·m
 - Bounce frequency between 0.5 and 0.7 Hz
 - Roll frequency between 0.3 and 0.4 Hz
 - Inhibit yaw and pitch
- Should
 - Propulsive action does not excite natural frequencies
 - Inhibit adult falling
 - Inhibit fishing and lounging
 - Negligible environmental impact

Construction

- Must
 - Material cost between \$2600 and \$3400
 - Material and installation tools transportable in between 8 and 12 HMMWV loads

Essential Problem Statement

Transport well-equipped hiking parties across a 150 ft. creek bed in safety and at low cost, with limited delay in hiking progress