

Managing System Design Process Using Axiomatic Design: A Case on KAIST Mobile Harbor Project

2010-01-0278

Published
04/12/2010Taesik Lee
KAISTGyung-Jin Park
Hanyang Univ.

Copyright © 2010 SAE International

ABSTRACT

As world-wide container volume increases and very large container ships emerge as a dominant player in the maritime cargo transport market, functional capabilities of container ports need to be greatly enhanced. To address this problem, KAIST is undertaking a project to design a novel container transport system, namely Mobile Harbor. Mobile Harbor refers to a system that can go out to a large container ship anchoring in the open sea, load and unload containers between the container ship and the Mobile Harbor, and transport them to their destinations. Designing Mobile Harbor presents a number of challenges as with many other large-scale engineering projects, especially at the beginning stage of the project. The challenges include diverse system mission scenarios that bring a wide range of different functional needs and constraints, large solution space with rather ambiguous concept selection criteria, difficulty in communicating ideas and concepts among many project participants with diverse background, and constant budget and time pressure, to name a few. For this kind of large, complex projects, the ability to effectively manage system design issues plays an essential role in determining the quality of outcomes of such projects. Properly defining and disseminating Functional Requirements, clarifying interface requirements between its subsystems, and identifying potential conflict, i.e. functional coupling, at the earliest stage of design as much as possible are all part of what need to be managed in a system design project. In this paper, we discuss the KAIST Mobile Harbor project to describe challenges and issues of system design, and illustrate how Axiomatic Design process can facilitate design tasks for a large, complex system.

INTRODUCTION

In response to the continued increase in global container cargo transport volume, a few major changes are expected in maritime cargo transport market. One of such anticipated changes is the emergence of very large container ships as a dominant force in the market. It has been predicted that container ships with cargo capacity of greater than 8,000 TEU¹ will occupy more than 25% of the entire container transportation volume by 2013[1]. The impending dominance of mega-containerships in the maritime container transport market calls for an improvement and/or restructuring of container handling infrastructure. For the existing large container ports, a key to this improvement is the ability to effectively accommodate mega-containerships. The hub-and-spoke structure for container transport network will get even more intensified with only a few gigantic ports functioning as a global hub port.

This trend has many implications for the container port design and operation. Those implications are 1) higher emphasis/priority on mega-containerships, which can potentially result in less-than-optimal service for smaller vessels, 2) increase in transshipment cargo and heavier reliance on feeder network, and 3) a need for on-demand cargo transport service. As environmental concern is becoming a norm in today's world, potential harms caused by traditional port construction and excessive overland cargo transport create a market for more environment-friendly solutions.

¹TEU (Twenty-foot Equivalent Unit): 1 TEU means a capacity to hold one box of 20-foot container. TEU is used to measure capacity in container transportation.

To address those issues, KAIST has proposed to develop a new container transport solution. Sponsored by Korean government in 2009, KAIST is undertaking a project to design a novel container transport system, namely Mobile Harbor. Mobile Harbor refers to a system that can go out to a large container ship anchoring in the open sea, load and unload containers between the container ship and the Mobile Harbor, and transport them to their destinations.

KAIST Mobile Harbor offers several advantages in improving the efficiency for ocean container transport. First, it does not require a large investment in infrastructure to construct a new port. Creating a port with a massive investment involves a significant financial risk. For some part of the world, it even turns out to be prohibitively expensive and not affordable to take on such a large SOC project. A port system based on Mobile Harbor is easily scalable and is not a physically fixed asset, which reduces risks and burden of a large-scale investment. Second, it offers flexibility in serving container ships. Since it is a mobile, agile asset as opposed to a fixed infrastructure, an optimal system configuration can be achieved to best serve changing demand of container transport market. Third, it creates an opportunity for sea liners to better plan their containership operation. With Mobile Harbor system, containerships are not bound by any land-based port but can be served in any location that best suits the business purpose and strategies of the liners.

Mobile Harbor is a large-scale system. From a system design perspective, it involves a multiple layers of hierarchy. At a higher level, a unit of Mobile Harbor is one of several system elements that comprise a Mobile-Harbor-based container transport system. At a lower end, designing a Mobile Harbor unit itself is a design problem with multiple subsystems. Also, the system boundary may become quite large. A Mobile Harbor system may include an existing, conventional port/terminal system and operation, in that it must be integrated with it. It may need to include part of sea liners' system, when it comes to container stowage planning and ship route decisions.

When undertaking a task to design this kind of a large-scale system, there are inherent challenges due to the complex nature of system design tasks. Size of the problem is large, which implies that there are large number of stakeholders to be considered; many decisions are dependent to each other and remain to-be-determined at the beginning of a project; and mission scenarios - how the system will be used - are open-ended. Most likely, the number of system requirements is very large. Also, there are many system level properties or emergent properties that are very difficult to translate into tangible design requirements. “-ility”, such as flexibility, extendibility, etc. is a good example of those kinds. For systems like Mobile Harbor, where there is no existing market and yet commercial success is the ultimate proof of concept, economic considerations are far from being

straightforward: target markets must be somehow identified even with insufficient information, and many system level decisions have to be made in the absence of proper understanding of their economic implications.

EARLY STAGE

KAIST Mobile Harbor project was initiated as an internal study by a group of KAIST faculty members in 2008, in response to the initial idea of mobile harbor proposed by the KAIST president Dr. Nam P. Suh in late 2007. The question raised by Dr. Suh, when he saw many container ships, harbored near the port of Singapore, waiting for their turn to gain access to an available berth, was “if a containership cannot come to a berth, why don't a berth come to a ship?” This question was the basis to develop an idea of a movable, floating platform with a container loading system on board (Figure 1).

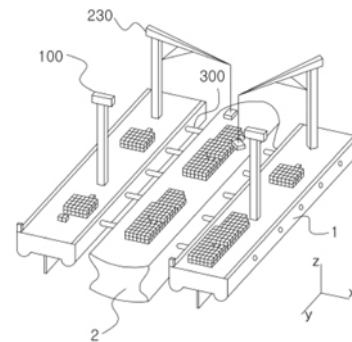


Figure 1. A concept sketch of Mobile Harbor at the early stage[2]

A more polished version of the idea later became KAIST Mobile Harbor concept. An interdisciplinary group of KAIST faculty members from mechanical engineering, industrial engineering, aerospace engineering, civil engineering and electrical engineering started a preliminary investigation in May 2008. This preliminary investigation was structured around the initial set of the functional requirements (FRs) set forth by Dr. Suh (Table 1).

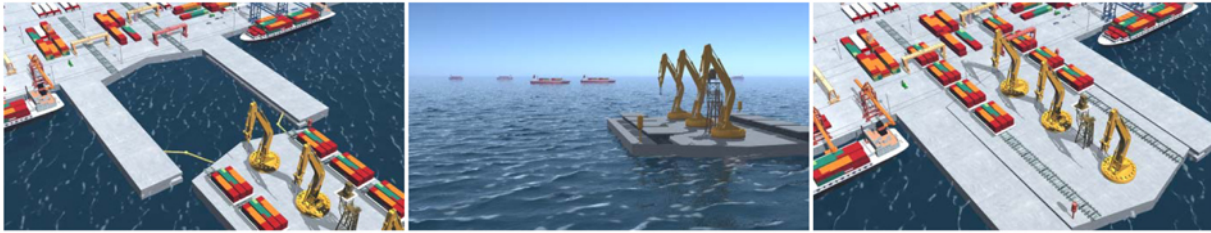


Figure 3. Illustration of a revised Mobile Harbor concept proposed to and approved for funding by a national R&D program

Table 1. Initial set of Functional Requirements and Design Parameters for early Mobile Harbor concept[2]

Functional Requirement (FR)	Design Parameter (DP)
Carry the load, i.e., cargo	Platform/float system
Propel the mobile harbor	Motor/propeller
Steer the mobile harbor	Steerable (rotation about the z-axis) propeller
Maintain the relative elevation of the mobile harbor	Float system with the ballast arrangement
Attach/locate to the stationary harbors	Triangular ends
Attach to the ship	"Suction" cups that allow small motions in three directions
Load the cargo	Robotized loaders
Stabilize the ship	Stabilizers
Quick loading/unloading at the stationary harbor	Railroad/freight cars
Locate the ship	GPS

Much of this early investigation was on understanding container handling operation, exploring architecture concepts, loading system (crane) controllability, and mooring alternatives [3]. During this period, Axiomatic Design analysis at the highest level was conducted to clarify why and how a Mobile Harbor concept decouples the currently coupled port system [4]. While individual studies of this investigation produced decent knowledge on many relevant issues of designing Mobile Harbor, it did not result in a coherent, solid outcome, leaving Mobile Harbor at the stage of a vague idea.

PROGRAM DEVELOPMENT STAGE

Based on the preliminary investigation results, KAIST endeavored to turn it in to a government-sponsored research project. The process by the government agency in charge was that multiple expert panels were formed to produce a program proposal for each of the potential projects, a review board

evaluates the proposals to select a subset for government funding, and a request-for-proposal (RFP) is issued for interested groups to respond to. This process spanned for about three months from November 2008 to January 2009. For Mobile Harbor program, several experts from ocean systems industry and academia worked together to refine the concept and define specific research items. Two researchers from the preliminary investigation at KAIST took part in this effort. At this stage, a few different embodiment ideas of Mobile Harbor were proposed. One of them includes a mobile floating terminal with Mobile Harbor shuttle (Figure 2).

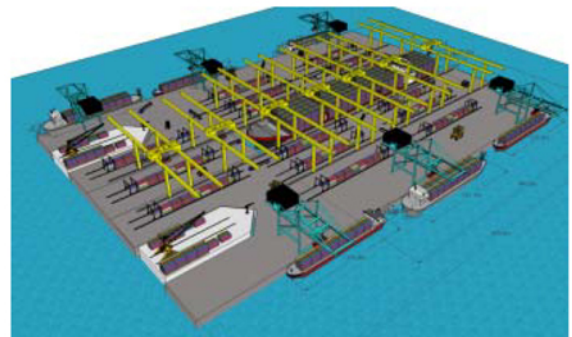


Figure 2. One of the early embodiment concepts of Mobile Harbor - Mobile Floating Terminal with Mobile Harbor Shuttle[3]

The response to this first proposal was negative, and a newer version of the Mobile Harbor proposal and a different channel for funding was pursued. Comments to the initial proposal were incorporated, and the new proposal concentrated on a more agile, smaller version of Mobile Harbor (Figure 3). This effort was carried out entirely by KAIST internal resource.

<figure 3 here>

After about three months of intensive effort to persuade the government, this proposal was finally accepted by the Ministry of Education, Science and Technology of Korean government. The program officially commenced in June 1st, 2009, approved for the fiscal year 2009. The effective project period was a little more than 7 months.