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IDENTIFYING THE SOURCES OF COMPLEXITY IN THE URBAN TRAIN PROJECT IN PUERTO RICO

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Abstract: The metropolitan area of San Juan in the Commonwealth of Puerto Rico has the highest concentration of vehicles per mile of paved road in the world. In order to improve the public transit system and decrease automobile dependency, the Commonwealth of Puerto Rico decided to embark on a major infrastructure project, which consisted on the design and construction of a heavy rail train to serve the Metropolitan Area of San Juan. The first phase of the project consisted of a 10.69 mile segment with 16 stations. This paper uses a five dimensional project management (5DPM) model and develops a complexity map to identify the sources of complexity in the project. The 5DPM model includes the following dimensions: cost, schedule, technical, context and finance. The results indicate that the major source of complexity in this project was the technical dimension which was complex due to variable site conditions and the owner's the lack of experience managing a project of this magnitude. Due to its scope and significance, the Urban Train project (Tren Urbano) provided an opportunity to train a group of young professionals who would later assume leadership positions in public projects in the Commonwealth of Puerto Rico. A structured professional development program was created in a partnership between the University of Puerto Rico (UPR) and the Massachusetts Institute of Technology (MIT). The professional development program consisted of 6 key elements: (1) MIT short course in public transportation in Boston, (2) UPR Winter short course on the Urban Train and Transportation in Puerto Rico, (3) Student research project, (4) Professional Practicum (summer work internship) (5) Site visit to an operating transit system, and (6) Possible employment opportunities with contractor or consultant. The paper concludes that including a professional development component in the project benefited the students and faculty who were involved. It also concludes that the professional development program contributed to managing complexity in the technical dimension for future projects and in the context dimension for this project by increasing public support to the project through marketing and dissemination efforts. This paper contributes to the body of knowledge by increasing our understanding on how to manage complexity in large transit projects and how to develop and implement a professional development program that contributes to project success.

1 INTRODUCTION

Public transportation systems are necessary in metropolitan areas to keep the traveling public moving while addressing traffic congestion (Bhattacharjee, S. and Goetz A. 2012). The metropolitan area of San Juan in the Commonwealth of Puerto Rico has the highest concentration of vehicles per mile of paved road in the world. In order to improve the public transit system and decrease automobile dependency, the Commonwealth of Puerto Rico decided to embark on a major infrastructure project, which consisted on the design and construction of a heavy rail train to serve the Metropolitan Area of San Juan (Fosbrook and Gonzalez 1997). The government of Puerto Rico did not have any experience in developing an urban rail system, therefore, they decided to establish a professional development program aimed at creating a group of professionals that could embark in future transportation projects. What better teaching tool that learning by participating in the single largest infrastructure project Puerto Rico had experienced in its recent history? Using this extraordinary opportunity to developed future professionals in infrastructure development showed forward thinking from the part of the government. Many of the students that participated in this project became involved professionally with the planning, design, construction and operation of the Urban Train. The professionals that were involved in the program also developed a special understanding of the project, since they had to interact with the students as mentors. This interaction proved effective during the project. As an example, the design of one of the stations was changed due to the interaction with the students.

Undergraduate and graduate students and professors from engineering, architecture and planning from two campuses of the University of Puerto Rico, namely, Mayaguez and Rio Piedras, as well as from the Massachusetts Institute of Technology (MIT) participated in the program. (González-Quevedo, et al. 1999, González-Quevedo, et al. 2000). The participation of MIT was justified because the metropolitan area of Boston and this particular university is known for its strong involvement in the planning, design and operation of urban rail systems. The interaction among the students, professors, and other professionals from both universities and the public and private sectors proved to be very beneficial for all involved and especially for the project.

1.1 Five-Dimensional Project Management

Traditional project management involves managing three dimensions to successfully complete a construction project. These three dimensions are cost, schedule and technical (also termed quality). Cost is quantifying the scope of work in monetary terms. Schedule are the calendar-driven aspects of the project. Technical are the typical engineering requirements. The traditional approach serves well for routine projects, however, as projects become more complex, optimizing the three dimensions is not enough to successfully complete complex construction projects. The difference between routine projects and complex projects revolves around the level of interaction and uncertainty between aspects of the project that are outside the project manager's direct control (Gransberg et al. 2013). In order to manage complex projects effectively, the project team must manage five dimensions: the three previously mentioned plus financing and context. Financing is the availability of funding and knowing how the project is going to be financed. Context are the political issues, procurement constraints, environmental requirements, public opinion, acquiring right-of-way, agency preferences/biases, and other similar issues (Shane et al. 2013).

The objective of this paper is to present a case study of a complex transportation project in the Commonwealth of Puerto Rico. The five-dimensional project management model was used to identify sources of complexity and rank each source on a relative basis to create a complexity footprint of the project.

2 METHODOLOGY

This study replicated the case study project protocol methodology that was developed for (the second Strategic Highway Research Program (SHRP 2) research project (Shane et al. 2013). Case studies can be used to gain insight on in-depth personal perspectives, behaviors, meanings, and experiences by obtaining details from a number of relevant or involved sources related to a project (Taylor et al. 2009; Yin 2002).The methodology involved using multiple sources of information including public records, project websites and media coverage, journal articles and interviewing the Secretary of the Puerto Rico Department of Transportation (DTOP). Multiple sources of information were used to cross-check that the information found in the data collection was accurate.

The structured interview questionnaire that was developed for the SHRP2 project was administered during the face-to-face interview with the Secretary of the DTOP. Per the U.S. GAO method, ample time was given to ensure that the interviewee understood each question and that the interviewer understood the responses (U.S. GAO 1991). The interview consisted of structured questions but the interviewee was able to deviate from the questions which allowed the interviewers to obtain valuable information that they had not originally contemplated. The interview also included the completion of complexity maps for the project. Complexity maps are a visual tool to manage complexity by creating a footprint. The first step to create a complexity map is to identify the sources of complexity in each of the five dimension (cost, schedule, technical, context and finance). A list of potential sources of complexity was provided to the interviewee. The interviewee was given the opportunity to select from the list provided as well as add any other sources based on his experience.

The second step is to rank the five dimensions in order of complexity where 5 is the most complex dimension and 1 is the least complex dimension. The third step is to assign a value to each dimension. A routine project with normal complexity has a value of 50. If the interviewee believes that the project is more complex than a routine project, a value higher than 50 is assigned. If the interviewee believes that the project is less complex than a routine project, a value lower than 50 is assigned. No two dimensions can be assigned the same value. The final step is to plot the data on a radar diagram and calculate the area of the pentagon (Gransberg et al. 2013). After the interview was completed, the authors discussed in-depth the data collected on the project (literature and interview) to gain an understanding and document the reasons for project success and the lessons learned.

3 RESULTS

3.1 Project Description

The Tren Urbano project is a heavy rail transit system in the San Juan Metropolitan Area in the Commonwealth of Puerto Rico. The heavy rail transit system connects three municipalities in the metropolitan area of San Juan: Bayamón, Guaynabo and San Juan. The scope includes 10.69 miles of heavy rail, 16 transit stations, and a tunnel. The project construction phase was divided into seven Design-Build contracts, one of them being a large Design-Build-Operate contract which included design, construction, power, communications, train control, signaling and the supply of cars, in addition to operation of the transit system for 5 years with a possible extensions. (Fulcher et al. 2004).

3.2 Complexity Map

The results of the complexity map exercise, as shown in Table 1, were used to determine the complexity footprint of the Urban Train. The results indicate that all five dimensions were significantly more complex when compared with the agency’s routine projects. The complexity footprint (Figure 1) shows that the technical dimension was the most complex. Next each dimension will be discussed separately to allow for identification of the sources of complexity by dimension.

Table 1: Rated Case Study Project Complexity by Dimension and Complexity Footprint Area

Dimension	Rank	Score
Cost	1	75
Schedule	2	80
Technical	5	95
Context	3	85
Finance	4	90

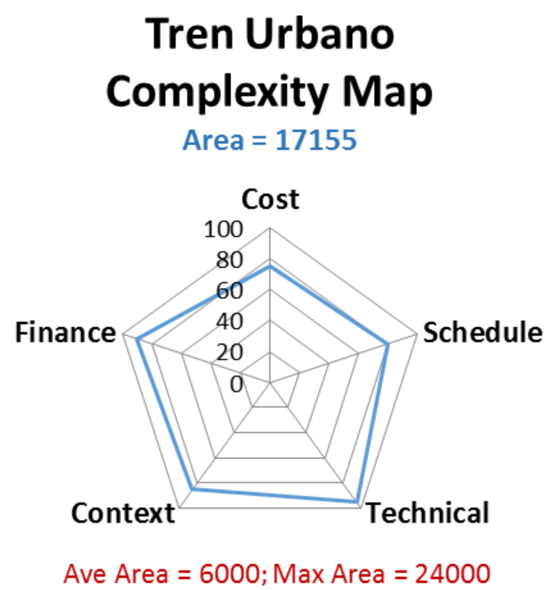

Figure 1: Tren Urbano Complexity Map

3.3 Cost Dimension

The original cost estimate was $1.2 billion. Changes in the scope of work and different site conditions increased the cost to $2.25 billion (Railway Gazette 2005)

3.4 Schedule Dimension

The original schedule indicated that the project would be completed in 44 months following the Notice-to-Proceed (NTP). The contract scope had to be increased several times due to additional works that were required to upgrade the aging utilities and to provide local community improvements. The changes in the scope resulted in time extensions. It took almost six years from NTP to project completion (Fulcher et al. 2004).

3.5 Technical Dimension

The technical dimension was ranked as the most complex dimension due to the site conditions where the project was built. The owner recognized during the planning state that the following issues will make the project more complex than routine projects:

- Densely populated historic area
- Variable site conditions
- Uncharted utilities and building foundations
- High water table (Fulcher et al. 2004)

The project was divided into 7 contracts to minimize the risk of a company defaulting and to allow multiple companies to participate in project construction phase. The main contract was a Design-Build-Operate contract, the remaining six contracts were design-build. Having multiple contracts allowed the agency to acquire the right-of-way (ROW) for each segment separately which was necessary to guarantee that the ROW of the first segment was completed prior to the 2000 elections. This reduced the likelihood that the project would be cancelled if the opposing party won the elections.

The owner had no experience designing and building a major transit project which greatly contributed to the complexity of the project. In order to address this weakness for future projects a professional development program was created. Since the lack of skilled project managers spans across the technical and context dimensions, details about the professional development program will be discussed in the context dimension.

3.6 Context Dimension

The project spanned several state government election periods. During the 1993 and 1996 election periods, the project had bipartisan support. This was not the case during the 2000 elections where the opposition party was against the project due to the cost increase, project delays and concerns about the contractor's ability to successfully complete the project. In order to keep the project moving forward, a significant effort had to be made to counteract the negative press.

The construction industry in Puerto Rico during the late 1990's and early 2000's was booming which resulted in a shortage of skilled labor for the project. In addition to the shortage of skilled labor, there was a shortage of trained young professionals who could assume leadership positions. In order to address this challenge, a structured professional development program was created in a partnership between the University of Puerto Rico (UPR) and the Massachusetts Institute of Technology (MIT). The UPR/MIT/Urban Train Professional Development Program (González-Quevedo et al. 1999, González-Quevedo et al. 2000) was and integral part of the Urban Train Project due to the fact that the government of Puerto Rico realized it needed to develop a group of professionals that could plan, design, construct and operate the Urban Train in its present and future conceptions. The program was managed from the government's side by the General Management, Architectural, and Engineering Consultants (GMAEC). The University of Puerto Rico through its Civil Infrastructure Research Center (CIRC) managed the project from the university's perspective.

The professional development program consisted of five major components: 1) an educational experience that lasted a week at MIT during the summer; 2) an educational experience that lasted a week in Puerto Rico early in January; 3) a visit to a city with a fully function heavy-rail public transportation system (e.g., Medellin, Caracas, Bilbao, New York City and Miami); 4) a research experience for the students in a project related to the Urban Train, with the participation of professionals involved in the project as advisors and professors as advisors; and 5) a summer internship with the GMAEC, the government, one of the contractors or designers. The University of Puerto Rico, through its CIRC, kept a record of the accomplishments of the program by measuring the number of students who were involved the professional development program and their career growth. Many of them obtained jobs related to transportation infrastructure development and some of them proceeded to further their studies by obtaining advanced degrees.

3.7 Finance Dimension

The Federal Transit Administration in 1993 included the Tren Urbano in its list of Turnkey Demonstration Projects. Through this arrangement the government of Puerto Rico provided 57% of the financing for the project, while the Federal Government provided 18% through its New Start Funds and 25% from other federal transportation funds. (Scheinberg 2000)

4 CONCLUSION

The five-dimensional project management model was used to develop complexity maps to identify the sources of complexity in the Tren Urbano project. The 5DPM model included the following dimensions: cost, schedule, technical, context and finance. The results indicate that the major source of complexity in the project was the technical dimension due to the site conditions where the project was built and due to the fact that the owner had no experience designing and building a project of this magnitude in the Commonwealth of Puerto Rico. Realizing that a professional development program was needed to address the lack of experience in designing and building complex projects by the owner and transportation professionals in Puerto Rico was a wise decision.

Future extensions of the Urban Train as well as other major rail transportation project will benefit from the creation of a cadre of professionals much better prepared to handle such projects. This program was very successful and the Commonwealth of Puerto Rico still benefits from having skilled project managers, who were part of the program, managing current projects. The professional development program contributed to managing complexity in the context dimension by increasing public support for the project through marketing and dissemination efforts. This paper contributes to the body of knowledge by increasing the understanding of project managers, transportation professional and academia on how to manage complexity in large transit projects and develop and implement a professional development program that contributes to project success.

The cost and schedule dimensions were ranked the least complex among the five dimensions of complex project management. However, it is important to note that the project experienced significant cost overruns and schedule delays. The main limitation of this study is that the results may not be applicable to other similar projects or other locations.

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