

# The Critical Success Factors for Manufacturing Execution Systems Adoption in the Defense Industry of Turkey: An Industrial Case Study

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## Abstract

The main objective of this paper is to investigate the Critical Success Factors (CSFs) of Manufacturing Execution Systems (MES) adoption using the case of a Turkish defense industry firm with both a quantitative and a qualitative research design. After the critical factors that are used in the adoption and implementation assessment in different countries and sectors are determined in the literature, about one hundred questionnaires and five interviews are conducted at a defense industry firm. The paper draws upon Information System (IS) success models and Enterprise Resource Planning (ERP) research models to develop and test a model of MES adoption to the extent of individual use effect and the individual work performance effect as dependent variables. The results of the analysis reveal that communication and business process reengineering are positively related to both dependent variables, while complexity of MES has a negative relationship with individual use effect. Top management/supervisor support and compatibility of software and hardware are positively associated with the adoption of MES. Moreover, qualitative analysis shows similar results, and thus increases the validity of the findings. The results indicate that more customization is needed and more attention should be paid during the MES implementation for better adoption.

**Keywords:** Manufacturing execution system, Critical success factors, Defense industry.

## Başlık

Türkiye Savunma Sanayiinde Üretim Yönetim Sisteminin Yayılmasındaki Kritik Başarı Faktörleri: Bir Endüstri Vaka Çalışması

## Özet

Bu çalışmanın temel amacı, bir Türk savunma şirketinde hem nicel hem nitel yaklaşımlar kullanarak vaka incelemesi yoluyla üretim yönetim sisteminin (ÜYS) yayılmasındaki kritik başarı faktörlerini araştırmaktır. Yayılma ve uygulama değerlendirmesinde kullanılan kritik faktörler farklı ülke, sektör ve akademik kaynaklardan yapılan araştırmalardan sonra tespit edilmiş ve bunun sonucunda yüz kişilik anket uygulaması ve beş farklı kişiyle de bire bir görüşme yapılmıştır. Çalışma, ÜYS'nin yayılmasındaki kritik başarı faktörlerini bazı bilgi sistemleri başarı modelleri ile kurumsal kaynak planlaması araştırma modellerindeki bağımsız değişkenleri baz alarak ve bireysel kullanım ile bireysel iş performansın açıklamaya çalışmaktadır. Analiz sonuçlarına göre iletişim ve iş süreçlerinin yeniden yapılanmasının bağımlı değişkenlerle pozitif yönde ilişkili iken, ÜYS'nin karmaşıklığının bireysel kullanımda negatif bir etkisinin olduğunu ortaya çıkmaktadır. Ayrıca, üst yönetim desteği ve yazılım ile donanım uyumluluğu, ÜYS'nin yayılmasındaki etkili faktörler arasındadır. Dahası, nitel analiz, niceliksel analiz ile benzer sonuçları göstermektedir ve bu durum bulguların geçerliliğini artırmaktadır. Son olarak, şirket ihtiyaçlarına göre özel uyarlamaya ihtiyaç duyulmaktadır ve bu yapıldığında ÜYS'nin yayılması hızlanacaktır.

**Anahtar kelimeler:** Üretim yönetim sistemleri, Kritik başarı faktörleri, Savunma sanayi.

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## Introduction

Economic globalization and internationalization of operations are essential factors in the integration of partners, suppliers and customers within and across national borders, and thus, the objective is to achieve integrated supply chains. The global nature of modern marketplace requires active players to internationalize their operations in terms of production, logistics and also research and development (R&D). In the past, companies competed based on one or two competitive performance objectives such as quality and price. However, present markets demand both price and quality in addition to greater flexibility and responsiveness, and hence, today's organizations must compete based on all competitive objectives. Therefore, today's world includes great challenges and needs more coordination and collaboration.

Information Systems (IS) such as Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), Manufacturing Execution Systems (MES) and many others are able to meet the needs of companies in terms of flexibility and responsiveness. These are software packages to manage company resources in an effective manner.

When we examine the ERP systems, which might be business software packages, we see that they impose standardized (predetermined) procedures on the input, and thus use and disseminate data across an organization, and integrate business processes. ERP systems have many modules such as financials, manufacturing, supply chain management, project management, customer relationship management, and MES (known as a kind of ERP module or layer between shop floor level and management level).

As far as MES is concerned, it could transform information management by creating a paperless shop floor tracking and managing the paperless-based shop floor environment. It enables to obtain critical information and collecting data from the shop floor and transacting in real time like other enterprise systems (e.g. another ERP modules: finance, purchase etc.). It also allows shop floor personnel to record and monitor shop floor activities in a highly efficient and effective manner. Having such information about production/materials when they occur allows planning departments to identify and prevent potential problems or bottlenecks.

ERP, MES or other software packages assist the company in terms of time-to-market entry, flexible and cheap design/production, resource utilization, and thus, the company can compete with local and global competitors. Nowadays, Industry 4.0, which was coined by the German Government and Siemens in 2011, covers cyber-physical world (smart factory), PLM, ERP, MES, machine to machine (M2M), vertical-horizontal integration of systems, robotic-systems, internet of things (IoT), big analytics, cloud computing, virtual reality and so forth. However, some firms are not aware of these systems or some firms are not successful at the implementation of these information systems. The main purpose of Industry 4.0 or digitalization is the connection of each system which is related with industrial production/design, to obtain real time data from anywhere, and to increase value by using these data.

MES is a new management tool or technology that enables an integrated approach to run business. Organizations apply this information technology tool to improve the overall company performance. Also, they must understand what the meaning and advantages of software program are for their employees since the use of ERP or MES might not be voluntary. Therefore, the

understanding of system adoption from the user's perspective is useful in helping the organizations prepare their employees to face new challenges and to teach the company using these technologies. In the IS literature, authors emphasize that business units or departments of an organization should work together to achieve its overall IS strategies and objectives, which requires each unit of company not only to work efficiently and effectively but also to understand how IS activities and decisions about IS affect the functions of other units (e.g. Nah et al., 2001; Sarker and Lee, 2003 etc.).

The above mentioned importance of the IS system thus entails the measurement of the success and effectiveness of the information systems, which is critical in understanding the value and efficacy of IS management actions and IS investments (DeLone and McLean, 2003). ERP and MES systems have been qualified as the most important developments in the corporate use of Information Technology (IT) between the 1990s and 2000s (Davenport, 1998). However, the implementation or adoption of enterprise systems is not only costly and complex but also it is a painful process. While some companies have achieved significant efficiencies through ERP or MES, others have complained about failed implementations/adoption, budget overruns, and disappointing performance (e.g. Fryer, 1999; Campbell, 2000).

The main objective in this study is to focus on the critical success factors of MES adoption, which may be defined as essential aspects of MES adoption processes in order to utilize MES benefits. Thus, we investigate not only the organizational factors but also the technological factors and innovative characteristics of software package for better diffusion since early adopters of a package might better benefit from it both individually and organizationally.

For a comprehensive investigation, this study follows a case study approach. The selected case is one of the largest defense companies in Turkey which also uses IS systems such as ERP, PLM and MES. This study investigates how MES was adopted and how MES adoption contributed to employee's outcomes and organizational changes. These issues have recently become a hot debate in the IS literature. Many studies have shown that there is a negative impact of IS or ERP adoption on employees because of organizational politics and power (e.g. Dery et al., 2006; Tatari et al., 2008; Garg, 2010; Ozorhon and Cinar, 2015 and many others). Hence, MES adoption process is worth investigating especially in a country like Turkey, which overly emphasizes adaption to Industry 4.0 or digitalization.

Project implementation success can be measured on time, budget and expected scope meeting dimensions. Using quantitative analysis, only scope meeting requirement is specifically emphasized in terms of individual use and individual performance effect in this study. Besides, qualitative analysis is used to validate the findings of the quantitative analysis. In the quantitative analysis, a questionnaire is conducted to about one hundred employees who work in the defense company mentioned earlier and have different roles such as project managers, key users and analyzers who are usually white-color employees and only data entry employees who are generally blue-color workers. In the literature, on ERP adoption, the analysis only focuses on project managers or key users of a company. Yet, we concentrate not only on project managers and key users but also on blue-color employees who work in shop floor and whose main job is data entry which is a novelty of this study. Gathering perspectives of all stakeholders enhances the validity of findings. For qualitative

analysis, one-to-one interviews are conducted with five different employees (middle-level managers) who have been working in MES project-related areas to strengthen analysis.

On the other hand, this paper contributes to critical success factors for IS implementation and adoption in the literature along four dimensions. First, to our knowledge, this is the first study which uses both quantitative and qualitative research approaches. Most of the studies in the literature focus on one type of research approach, particularly quantitative approach. Second, blue-color employee's views are considered and the methodology design of research is thus novel, which enables a more comprehensive analysis. Third, to the best of our knowledge, this is the first study that examines MES adoption (in Turkey) though there are many others that examine the IS implementation in general. Last, this study helps policy makers or company managers to understand critical success factors before for better implementation success. Therefore, this study is an onset for future research on MES implementation. The following research questions are addressed to better understand deployment:

- What critical success factors affect MES Success? Why are these factors critical to MES implementation and adoption?
- Does MES help employees in performing their job (individual effects)?
- Is MES a beneficial solution for the organization?

## Methodology & Results

This study is based on a single case study which includes quantitative and quantitative analysis. However, quantitative analysis is the primary analysis method in this paper that uses survey questions and principal component analysis (factor analysis) for data reduction. Later, the study employs simple ordinary least squares (OLS) estimations. On the other hand, qualitative analysis is only utilized for increasing the validity and reliability of this study.

Organizational factors and technological/innovative factors are independent variables; and individual impact in terms of use and performance are used as dependent variables in this study. Figure-1 shows research model.

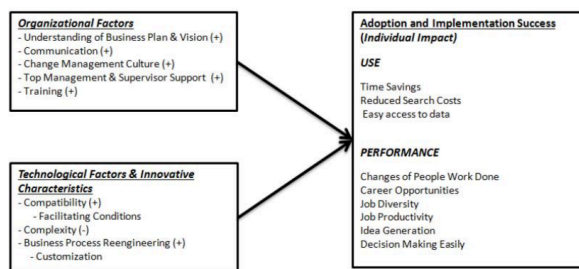


Figure 1. Research model of the study.

Moreover, the following table (Table-1) shows the results of regression analysis (quantitative part of analysis). The qualitative analysis results are similar to quantitative analysis. According to qualitative analysis, the participants say that business process reengineering, user interface changement, compatibility of system, top management support and culture are most important factors.

## Discussion & Conclusion

There is a comprehensive body of information about MES implementation and adoption issues in Defense Industry, which focuses on both research and development as well as

manufacturing. MES helps company to follow production status, material flow, resource usage rate and following production/quality steps in operation stage level. Now, company use MES outputs for better manufacturing management compared to the past. Both qualitative and quantitative analyses, communication, top management & supervisor support, compatibility, complexity and business process reengineering are coming in view as the most significant critical factors for adoption. In addition, qualitative analyses revealed change management as a significant phenomenon.

Table 1. Hypothesis testing results.

Hypothesis	Variables	User Use Effect	Perceived User Performance Effect
H1	Understanding of Business Plan & Vision		
H2	Communication	(+) ***	(+) **
H3	Change Management Culture		
H4	Top Management & Supervisor Support	(+) *	
H5	Training		
H6	Compatibility		(+) *
H7	Complexity	(-) ***	
H8	Business Process Reengineering	(+) ***	(+) ***

\*\*\* Significant at 1%. \*\* Significant at 5%. \* Significant at 10%.

This study explains and confirms that communication and business process reengineering are the most critical success factors for MES adoption. Communication is an organizational factor while business process reengineering is a technological factor. Ngai et al. (2008) suggest that business process reengineering can be added to the organization-related factors. In this regard, organizational factors might be more worthwhile for IS implementation as explained by Zhang et al. (2005), Tatari et al. (2008) and Garg (2010).

Communication is crucial to avoid misunderstandings as it hampers potential conflicts during the implementation process of IS system. In addition, it provides user involvement: users may develop a sense of ownership of the project. Building confidence between implementation team members via communication plays an important role in success. Communication is also needed to align all parties to create a common understanding of the project, leading to a consensus over project goals. Ozorhon and Cinar (2015) revealed that communication is indeed significant. In addition, other literature (e.g. Zhang et al., 2010; Madsen, 2005) sometimes added this factor in top management, clear goals and objectives and project management factors. Communication also reflects a unique culture, the corporate identity of an organization. Openness in communication might increase the impact of MES.

On the other hand, the era of legacy systems might become a hurdle to both business process reengineering and MES implementation, and lead to additional requirements for the MES project team to satisfy. For instance, MES practitioners state that some user interfaces should be changed to reach more user-friendly application. As a result, the company earns new terminologies that are related to production logistic. Moreover, new report formats which are in failure in MES implementation by using best practices packages are occurred by project team. These and the in-depth interview with all parties show that customization is required. Besides, interviews show that MES packages sometimes fail to satisfy local requirements (e.g. energetic area requirements). In addition, the more customization is expected to lead to higher user satisfaction, leading to positive impacts on individual productivity, resulting in organizational productivity improvements according to the interview.

Top management is the key enabler to overcome many problems such as the resistance of other employees, achieving business process reengineering and any dysfunctional aspect of the organizational structure or the business processes (Negahban et al., 2012). Technology use is sometimes voluntary and mandatory. Top management has a critical role for mandatory environment. On the other hand, user involvement is also crucial for voluntary environment. Apart from this primary support of top management, political and behavioral support is also important for the development to run smoothly, especially when there is significant resistance from the staff. Furthermore, the attitudes, beliefs and experiences of managers might have adverse impacts on the IS success and top management support (Ngai et al., 2008). In this study's literature review, eight of the twelve articles that we have reviewed previously comprise qualitative or quantitative analysis methods that cite top management support as a critical intervention.

Complexity has an inverse relationship with MES implementation and adoption. Comparable results are reported in many other studies such as Wu and Wang (2006), Wang and Liao (2008), Petter and McLean (2009) and many others. For instance, Wu and Wang (2006) found that user attitude is influenced by beliefs about complexity of system, which then impact on user use and embody user's attitude. Moreover, it only ensures standard IS use and does not alter user perceived performance or benefits. On the other hand, complexity is related to easy use of user screens. It is shown that employees prefer the screen to be user friendly and resemble a social media interface.

Zhang et al. (2005) and Chang et al. (2008) also found equivalent results like our study in terms of compatibility construct. Compatibility compromises hardware and software communication and companies may have different constraints in this regard. For instance, defense industry has a wireless problem and so tablets might not be used widely when using MES in shop floor. Therefore, before implementation of such a system, company should think similar constraints which can be company or country specific. This construct has not been researched in detail (to the best of our knowledge) so that our study result may be one of the beginning researches.

Despite the similarities between other studies, this study reveals that communication and business process reengineering is more important than other studies (e.g. Bradford and Florin (2003); Zhang et al. (2005); Tatari et al. (2008); Garg (2010) etc.) since others emphasize on understanding on business plan, top management support or training. Moreover, this work contains both quantitative and qualitative approach for analysis and validation therefore it is more comprehensive. Besides, blue-color employees' views are considered in this study and their view is changing in corporateness, job performance effect, user satisfaction and user-friendly application constructs.

The implementation and deployment of IS systems are not an easy process because it contains high levels of complexity and uncertainty: too many people are related to these projects, implementation budget is usually high, and pressure of top management is huge. Therefore, stress levels of the project manager are usually high. Information systems enable companies to reach digitalization and automation of company goals. However, cultural issues, functionality requirements (different stakeholders' necessities), IS practices (IS has best practices structure but it may be barrier of business process reengineering), communication, top management support, user and vendor involvement, complexity of

IS etc. are key factors for good implementation and adoption. Hence, before applying IS technology in a company, following steps should be considered:

- Defining company requirements,
- Prioritizing requirements,
- Checking requirements whether they match the purchase application/software infrastructure or not (Business process reengineering is critical at this point. Moreover, compatibility between hardware and software and complexity of software is crucial for success.),
- Strengthening the IT department power such as reorganization or enable it C-level representation such as Chief Digital Officer (This is important for top management support),
- Organizing awareness seminars or pre-trainings (These include change management awareness and software structure trainings) before implementation,
- Last but not least, there should be a communication plan for these project implementation and adoption. Also, project management group has power for implementation and they should define communication frequency between all stakeholders.

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