JOURNAL OF MANAGEMENT AND ENGINEERING INTEGRATION

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Time Postponement: Modified Models to Improve Delivery Lead Time

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Abstract

To meet what exactly customer demands in terms of product specifications and quantity, firms try to delay some production and logistics operations. These strategies are known as time, form and place postponement. In time postponement, the focus of this study, a number of value adding activities is delayed by the time more accurate information about customer demand is received. The main shortfall of time postponement is prolonging delivery lead time. To improve the performance of production and logistics time postponement, this paper introduces four modified postponement models. Models are developed to postpone forecasting, finishing and shipment operations. Buyer's waiting time and the mismatch between shipment quantity and real demand quantity are defined as the performance criteria for the postponement model.

Modified postponement models indicate considerable improvement in performance criteria, and provide important contribution to the implementation of time postponement strategy.

Keywords: Time Postponement, Packaging postponement, Logistics Postponement.

1. Introduction

Postponement has been recognised as a supply chain strategy which provides more product variety and more accurate forecast, reduces inventory and logistics costs, and improves customer service [1-3]. Postponement is described as delaying some value adding activities in the supply chain until more information about customer order is received [4,5]. Despite its simple definition, postponement is coupled with complexities in theory and practice. Identification of activities to delay, postponement time and form, inventory planning in the delayed activities, and postponement requirements and enablers are challenges of postponement strategy [1,6]. The literature review has indicated that it is widely required to study techniques which maintain or enhance application of postponement strategies. It has also been highlighted by the literature that despite many studies on the benefits of postponement, little is still known about its implementation [1,3,7].

This study discusses a postponement problem while it focuses on the postponed packaging, labelling and shipment operations. Two performance criteria for the applied postponement strategy are considered: buyer's waiting time and the mismatch between the real demand and the amount shipped to the buyer. Clearly, by postponing some operations, there is a higher chance to provide customer with what exactly it demands. On the other hand, the delivery lead time which is called buyer waiting time in this study will increase.

Distancing from full postponement model, this study tries some modified postponement models. Models include postponed forecasting and a mixture of postponed forecasting and postponed finishing (packaging and labelling) and shipment operations. Developing the modified postponement models (postponed forecasting and a combination of postponed forecasting and postponed finishing and shipment) is the main contribution of this paper.

2. Case study description

Data collection and testing the models are based on a case study in clothing industry, in a men's underwear and sock maker. The men's underwear and sock firm which is called company Alpha later on, makes its products based upon limited predetermined designs and production processes. Changes in design or material happen not often. Even the colour mix is fixed. Products in this firm are distributed through wholesalers (which are called 'buyers' later in this paper) which update information of the consumer market frequently. Wholesalers send their orders to the company Alpha almost regularly. Changes in demand usually happen to the packaging, labelling and quantity of the orders. As the main alteration in orders occurs in the last stages of the production process and quantity of shipment, the company Alpha considers the application of packaging and labelling and shipment postponement. In next section, this study starts with modelling no-postponement and full-postponement situation. Then it tries to modify the initial models to improve the performance of the systems in terms of buyer's waiting time and mismatch with the buyer's order.

3. Problem description and the models

This study focuses on the last stages of the production process of the company Alpha and the shipment of the product to the buyer's site. The last stage of the production process includes packaging and labelling which can slightly be customised based upon the buyer's order. The slight customisation means that packaging and labelling (later on called "finishing stage") can vary for different orders, although the operations and their time are almost similar.

The models introduced in this study focus on time postponement of the finishing operations and shipment. The main incentive to pursue time postponement strategy is matching supply and demand in a fluctuating demand situation.

The time postponement problem is analysed by two basic models and four modified models. Two basic models include "early finishing" (no postponement) and "postponed finishing" (full postponement). In early finishing, postponement is not applied. Products are packaged and labelled according to the forecast much prior to receiving customer order. Quite the opposite, in full postponement, product is not prepared and shipped before receiving customer order. Focusing on the time postponement approach, this study tries to overcome its main shortfall which is long delivery lead time. To do this, four models (called "modified models") are developed to improve the full postponement model. Before explaining each model individually, assumptions which are considered in the models are explained. The assumptions largely reflect the real-life situation of the case study described earlier. Simplifying assumptions are applied if necessary.

3.1 General assumptions

To consider the finishing operations time in the models, parameters θ and τ are defined as follows:

θ: Finishing time for each unit of product (hour/unit).

τ: Time available in each period for finishing operations (e.g. 8 hours if a period is assumed as one working day).

Thus, total number of products which can be produced (finished) in each period is τ / θ.

Products are delivered to the buyer in one shipment. Shipment time is shown by Lr and is defined as:

Lr: Transport lead-time – duration of shipping products to the buyer's site (hour).

Finishing operations and shipment are considered in a planning horizon T. Each period is indicated by index t. Hence, $t \in T$. In the current case study, each period t refers to "one day".

Buyer's demand is received by direct order, and also is forecasted by the company Alpha. They are notated as:

Dr_t : Real demand (buyer's order) in period t

Df_t : Forecasted demand for period t

When a buyer places its order in period t, the target is meeting buyer's demand as quick as possible. This is mainly because of the volatile final consumer market and its impact on the company Alpha's buyers. Thus, buyers have no accurate plan when exactly they need the order they place in period t. Roughly, they just need it for near future. In that respect, the company Alpha has two main options; finishing and shipping products based on the demand prediction or delaying those operations by the time it receives buyer's order in each period.

In the first approach, delivery is done in advance. Although the buyer receives the product on time, as shipment is done based on the prediction, it may be not exactly what they want in terms of quantity and minor customisation in packaging and labelling they need. In the second approach, the buyer will exactly receive what it orders but with a time lag – which is usually lengthy.

Two variables of the models which show buyer's waiting time and difference between the delivery quantity and the real demand are defined as:

BWT: Buyer's waiting time (hour) - the time between the buyer's order and product delivery (see Figure 1).

ε_t (Error): the difference between real demand (buyer's order) in period t and product units prepared to meet that demand (of period t) based on the forecast for period t.

3.2 Advanced shipment model

In advanced shipment model, decision about the quantity which should be sent to the buyer's site is made based on the forecast. Forecast data is received from master planning department which generates and updates demand forecast information. Finishing operations and shipment are done in advance, regardless to the real order of the buyer - which may be received in few periods. Number of products delivered to the buyer in this model is indicated by Xs_t.

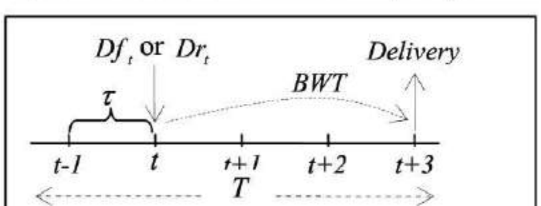

Figure 1. Time elements of the postponement models.

Xs_t : Advanced shipment based on forecast for the demand of period t (units of product) when finishing and shipment operations are done much earlier than period t.

As explained above, Xs_t follows the forecasted demand for period t. Hence, $Xs_t = Df_t$. As products are finished and shipped to the customer prior to the customer order, thus, $BWT = 0$. Error, is also defined as $\varepsilon s_t = |Dr_t - Xs_t|$.

3.3 Full postponement model

In this model, finishing operations start once the company Alpha receives the buyer's order. Output of the finishing stage (Xp_t) is equal to the buyer's order for period t (Dr_t). The same amount is shipped to the buyer. As defined earlier, the finishing operations take $Dr_t * \theta$ and shipment takes Lr hours. Hence, $BWT = Dr_t * \theta + Lr$. As the amount of the products delivered to the buyer is exactly same as what the buyer's ordered, the error is zero ($\varepsilon p_t = 0$).

3.4 Modified postponement models

To improve the long buyer waiting time (*BWT*) in the full postponement model and the high error (εs_t) in advanced shipment approach, four modified models are developed. All of them follow the time postponement strategy, with some modifications. In modified models, finishing and shipment of the demand at period t are delayed, but not until the period t. Instead, modified models try to generate more accurate forecasts of the demand in a nearer time to period t, or to mix the forecasting data and buyer's order. Details of each model are explained in the following sub-sections.

3.4.1 Modified postponement model *I* and *II* - postponed forecasting: Modified postponement models *I* and *II* are explained in one sub-section as the rational of both is same. They just use different criteria in their forecasting.

In both models finishing operations (and consequently, shipment) of the demand in period t start k period earlier. k is much closer to period t, than the time of general forecast generated by the master planning department of the company Alpha. Once the forecasting and planning are done (for period t in period t-k), the company follows it, regardless to the buyer's order (real demand) for period t which may arrive shortly.

In the modified postponement model *I*, the demand of period t is forecasted in period t-k, and finishing and shipment operations start in the same period (t-k). Number of products which are planned to start operations of finishing in period t-k is indicated by $XmI_{t,k}$, and is defined as:

$XmI_{t,k}$: Modified postponed finishing (Model *I*) for the demand of period t when finishing operations start in period t-k (units of product).

$XmI_{t,k}$ is identified by the demand forecast generated in period t-k. That forecast is based on the general demand forecast for period t and the buyer's order (real demand) in period t-k. Thus, it is given by:

$$XmI_{t,k} = (Df_t + Dr_{t-k})/2$$

As the emphasis of all modified models is on the time postponement strategy, they try to work as much as possible with real data. In view of that, they avoid to follow complex forecasting systems which are mostly inefficient in prediction of lumpy intermittent demand.

Error and *BWT* in the modified postponement model *I* are calculated as:

$$\varepsilon mI_{t,k} = \left| Dr_t - XmI_{t,k} \right|$$

$$BWT = (XmI_{t,k} * \theta + Lr) - k$$

In the modified postponement model *II*, the demand at period t is also forecasted in period t-k, and finishing and shipment operations start in the same period (t-k). Number of products which their finishing operations are planned to start in period t-k is indicated by $XmII_{t,k}$, and is defined as:

$XmII_{t,k}$: Modified postponed finishing (Model *II*) for the demand of period t when finishing operations start in period t-k (units of product).

$XmII_{t,k}$ is identified by the demand forecast generated in period t-k which is based on the buyer's order (real demand) in period t-k. It is calculated as $XmII_{t,k} = Dr_{t-k}$

Error and *BWT* in the modified postponement model *II* are:

$$\varepsilon mII_{t,k} = \left| Dr_t - XmII_{t,k} \right| = \left| Dr_t - Dr_{t-k} \right|$$

$$BWT = (XmII_{t,k} * \theta + Lr) - k$$

3.4.2. Modified postponement model *III* and *IV*- postponed forecasting and finishing: Modified postponement models *III* and *IV* both follow same rational, but they use different criteria in their forecasting.

In both models finishing operations (and consequently, shipment) of the period t demand, start k period earlier. The forecasted amount in this model is equal to the forecast of the first modified model ($XmI_{t,k}$). Once the forecasting and planning are done (in period t-k for period t), the company starts the finishing (and consequently, shipment). The finishing operations carry on by period t or by the time $XmI_{t,k}$ units are prepared. If all $XmI_{t,k}$ are prepared before period t, the shipment is also done. However, if total amount finished by period t is less than predicted demand for period t ($XmI_{t,k}$), the real demand of period t (Dr_t) is considered. If total amount finished by period t is more than Dr_t, then the finishing is stopped and finished items by period t are shipped to the buyer's site. If total amount finished by period t is less than Dr_t, then finishing is carried on by the time totally Dr_t items are prepared for the shipment. This modified model actually follows a mixture of forecasting and real data, where both forecasting and finishing are partially postponed. Variables of the Modified postponement model *III* are defined as follows.

$XmIII_{t,k}$: Modified postponed finishing (Model *III*) for the demand of period t (units of product) when finishing operations are postponed to period t-k

$$XmIII_{t,k} = \begin{cases} Dr_t & if \quad Dr_t > YmIII_{t,k} \\ YmIII_{t,k} & if \quad Dr_t \leq YmIII_{t,k} \end{cases}$$

$YmIII_{t,k}$ = Total production from period t-k to period t (in the Model *III*)

$$YmIII_{t,k} = Minimum\,(XmI_{t,k}, k * \frac{\tau}{C})$$

$$\varepsilon mIII_{t,k} = \left| Dr_t - XmIII_{t,k} \right|$$

$$BWT = XmIII_{t,k} * \theta + Lr - k * \tau$$

$$If\ XmIII_{t,k} * \theta \leq k * \tau$$

$$BWT = Lr$$

$$If \begin{cases} XmIII_{t,k} * \theta > k * \tau \\ and \quad XmIII_{t,k} > Dr \end{cases}$$

$$BWT = (Dr - \frac{k * \tau}{\theta}) * \theta + Lr$$

$$If \begin{cases} XmIII_{t,k} * \theta > k * \tau \\ and \quad XmIII_{t,k} \leq Dr \end{cases}$$

Similar to the model *III*, the modified postponement model *IV* uses a mixture of forecasting and real data. However, it applies the forecasting method of model *II*. Accordingly, variables of the Modified postponement model *IV* are defined as follows.

$XmIV_{t,k}$: Modified postponed finishing (Model *IV*) for the demand of period t (units of product) when finishing operations are postponed to period t-k

$$XmIV_{t,k} = \begin{cases} Dr_t & if \quad Dr_t > YmIV_{t,k} \\ YmIV_{t,k} & if \quad Dr_t \leq YmIV_{t,k} \end{cases}$$

$YmIV_{t,k}$ = Total production from period t-k to period t (in the Model *III*)

$$YmIV_{t,k} = Minimum\,(XmII_{t,k}, k * \frac{\tau}{C})$$

$$\varepsilon mIV_{t,k} = \left| Dr_t - XmIV_{t,k} \right|$$

$$BWT = XmIV_{t,k} * \theta + Lr - k * \tau$$

$$If\ XmIV_{t,k} * \theta \leq k * \tau$$

$$BWT = Lr$$

$$If \begin{cases} XmIV_{t,k} * \theta > k * \tau \\ and \quad XmIV_{t,k} > Dr \end{cases}$$

$$BWT = (Dr - \frac{k * \tau}{\theta}) * \theta + Lr$$

$$If \begin{cases} XmIV_{t,k} * \theta > k * \tau \\ and \quad XmIV_{t,k} \leq Dr \end{cases}$$

3.5 Computational Results and Managerial Implications

In this section, models developed earlier are applied in the case study for fifty periods. The real data and forecasting data applied for "full postponement model", "advanced shipment model" and the four modified models. The modified postponement models are run for all *k*s ($k \in \{1,..,5\}$. Finishing operations time, transportation time and working hours per day are 0.3, 8 and 8 hours respectively.

Figure 2 shows the mean absolute error (MAE) for all six models. MAE indicated the average of errors in fifty periods for which the models are run: MAE=$\sum_{t=1}^{50} \varepsilon_t$.

As illustrated by Figure 2, the advanced shipment model has the highest error, while the full postponement model has a zero error. By applying modified models, although MAE is still more than that of fully postponement situation, but considerable improvement is achieved comparing to the Advanced shipment model. It seems that the modified models *I* and *II* are not highly sensitive to *k*. That means while only forecasting is postponed, the system still confronts a high level of error, and relying more on the forecast (i.e. increasing *k*) does not reduce the error. On the other hand, models *III* and *IV*, which postpone both forecasting and finishing operations are highly successful in reducing the error. Those models are sensitive to *k*. This implies that by relying more on forecasting data (i.e.

increasing k) the error of the system is increasing as well.

The other factor which should be considered is buyer waiting time (*BWT*). As it is clear from the definition of Advanced shipment, the *BWT* is zero in that model. It is also expected that *BWT* is in its maximum in fully Postponement situation (see Figure 3). By modifying the fully postponement models and increasing k, all four modified models show improvement in *BWT*.

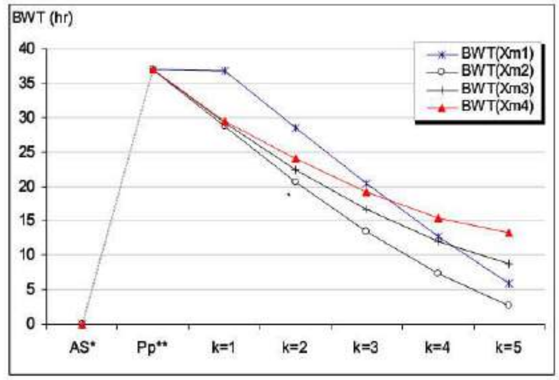

Figure 3. Buyer waiting time (*BWT*) in different postponement strategies.
* Advanced shipment, ** Fully Postponement

4. Conclusion

Advanced shipment and fully postponement approach have serious shortfall in meeting customer needs. Advanced shipment does not send the right quantity to the buyer (high error) and fully postponement ships the buyer's order with significant delay (high *BWT*). Modified models have tried to mitigate those shortfalls. Finding a k, which can satisfy both error and *BWT* is crucial. Right k varies in different systems and in different situations. It also depends on the importance of error and *BWT* factors for the buyer and operations management system as well.

In future studies, applying more efficient forecasting methods can be studied. Moreover, other performance criteria can be considered.

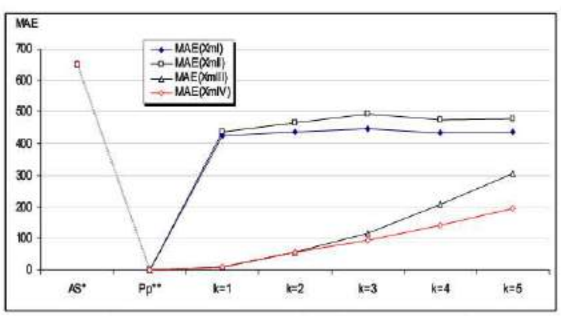

Figure 2. Mean Absolute Error in different postponement strategies.
* Advanced shipment, ** Fully Postponement

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Science TQM, A New Quality Management Principle: The Quality Management Strategy of Toyota

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Abstract

In this paper the author proposes, "Science TQM", a new quality management principle. This principle consists of the "Total Development System, TDS", "Total Production System, TPS", "Total Marketing System, TMS", "Total Intelligence Management System, TIS", and "Total Job Quality Management System, TJS". It aims to realize an integrated form of a next-generation management strategy.

Furthermore, this paper demonstrates how the utilization of "Science SQC" and a "Strategic Stratified Task Team" contributes systematically and organically to solving quality management problems. Its validity has also been verified through its application within the Toyota Motor Corporation, Toyota group companies, and others.

1. Introduction

Looking closely at the quality management issues facing advanced corporations both domestically and overseas in recent years, it has become clear that a new TQM (Total Quality Management) principle is being strongly sought after [1-2]. This new principle needs to employ a rational concept and methodology that will break away from the conventional ideas of quality management and contribute to the restoration of quality. In the main discussion of this paper, "a new quality management principle, the next generation of TQM - Science TQM" (Science TQM that utilizes Science SQC) [3], will be proposed and its effectiveness will be demonstrated. Science TQM systematically and organizationally contributes to the solution of company-wide management technology problems.

Science TQM is composed of five core principles, namely: (1) the Total Development System, TDS, (2) the Total Production System, TPS, (3) the Total Marketing System, TMS, (4) the Total Intelligence Management System, TIS, and (5) the Total Job Quality Management System, TJS. By implementing "Science TQM" and it's five core systems each work department will become equipped with the core technology and linked with one another cooperatively. This paper demonstrates how the utilization of "Science SQC" and a "Strategic Stratified Task Team" contributes systematically and organically to solving quality management problems. Its validity will then be been verified through its application within the Toyota Motor Corporation, Toyota group companies, and others [4].

2. The Key to Success in Global Production, an Evolution in Manufacturing

In this chapter, consideration is given to the "evolution in manufacturing" that is needed for dealing with the management issues facing Japanese manufacturers today. In other words, the key to success in global production is globally consistent levels of quality and simultaneous production worldwide.

2.1 The Japanese Production System which led Manufacturing in the 20th Century

The Japanese administrative management technology that contributed most to the world in the latter half of the 20th century can be typified by the Japanese production system represented by the Toyota Production System (TPS). TPS is a production system developed by Toyota that is also called JIT (Just in Time) or a "Lean System" in other parts of the world. This system aimed to improve product quality while pursuing maximum efficiency through the application of TQM (Total Quality Management) into the manufacturing process, as well as applying the principle of cost reduction [5-6].

In order to cater to the customers' needs and to conduct manufacturing successfully, a study into the timely "simultaneous achievement of QCD (Quality, Cost, and Delivery)" is the top priority. To accomplish this, Toyota has been focusing on TPS and TQM as the dual pillars of management technology [6-7]. As shown in Figure 1, through the combination of these two pillars, deviations visualized in the form of "large tidal waves" can be reduced to smaller fluctuations similar to "gentle ripples" that enable the improvement of average values at all times. This involves the continuous application and improvement of QCD study activities, while at the same time, incorporating SQC from the standpoint of hardware technology based TPS, and software technology based TQM, which are represented on the vertical and horizontal axes respectively [6].

As a result of being highly praised all over the world as the concept that revolutionized automobile production at Toyota, the concept of JIT and its approach have been established as a core concept of manufacturing around the world [8].

2.2 What are the Critical Management Issues for Japanese Manufacturing?

In recent years, consumers (hereafter called, customers) have been selecting products that fit their lifestyles and their set of personal values. Consequently, a market environment was created in which customers strictly judge the reliability of manufacturers according to the reliability (quality and value gained from use) of their products. For this

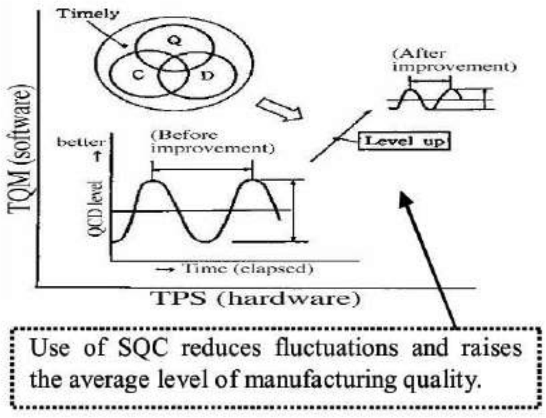


Figure 1. Relation between TPS and

reason, it is not an exaggeration to say that manufacturers' success or failure in global marketing will depend on whether or not they are able to precisely grasp the customers' preferences and are then able to advance their manufacturing to adequately respond to the demands of the times.

This is being done in order to realize global production that will achieve the so-called "globally consistent levels of quality and simultaneous production worldwide (production at optimal locations)" ahead of other manufactures. Achieving this will allow the manufacturer to not be pushed out of the market [4]. In the midst of the drastic changes taking place at the manufacturing site due to the use of digital engineering, we can say that the reconstruction of world-leading, uniquely Japanese principles of management technology and administrative management technology, which will be viable even for next-generation manufacturing, are urgently needed in order to keep up with this evolution in management technology [7].

This is the mission imposed on Japanese manufacturers today [4]. In order to accomplish this, it is imperative that management related departments, such as technical management, production management, sales management, and information technology, which make up the core of corporate management, closely cooperate with the administrative departments, such as personnel affairs, general planning, TQM promotion, and overseas business. Furthermore, management

-related departments also need to carry out strategic collaborations with on-site departments handling technical, production, and sales matters, as well as with suppliers (parts manufacturers) [3-4].

2.3 The Evolution of Administrative Management Technology is Now Being Demanded

In today's rapidly changing technological environment, one of the first management technology issues that needs to be addressed in order to realize the "simultaneous achievement of QCD" and place the customer first, is the creation of a new development designing system capable of reforming the technological development business processes of the development designing-related departments. Second, it is increasingly important for departments concerned with production to develop new production technologies and advance the "production management technology system" that enables global production. Third, it is necessary for sales-related departments to concentrate their view on global marketing and to establish a "new marketing system" that breaks away from the conventional systems in an effort to strengthen ties with the customers.

Furthermore, it is becoming increasingly necessary, even from the standpoint of assuring "corporate reliability", for the general administration departments and management-related departments to cooperatively establish and implement a new administrative management technology which enhances the business processes of all departments involved in corporate management [3,7]. The above statements also apply, without exception, to Toyota's TPS, which has been adopted and further developed in various systems shared internationally, such as JIT or Lean Systems [9], and therefore, it is no longer Toyota's exclusive technology. In the United States as well, the importance of quality management has been increasingly recognized though studies of Japanese TQM. TQM has been actively promoted, thus encroaching on the quality superiority that Japanese products have previously enjoyed [10-12].

What can be deduced from these facts is that it is clearly impossible to continue to lead in the next generation of manufacturing simply by adhering to and maintaining the traditional, production-based "Japanese management technology". In order to overcome these problems, it is essential not only to advance TPS, a core technology of production processes, but to also establish a core technology for the service and sales, development designing, production, general administration, and management-related departments [3-4].

Furthermore, for the purpose of ensuring the reform of the business process in all departments, as well as reinforcing inter-department cooperation, it is vital to reconstruct an intelligent system for sharing information. During the implementation stage of this system, it will be important to further upgrade the advantages of the "Japan Supply System" [3,13], a cooperative system between the assembly parts manufacturers and the automobile manufacturers that has long been a part of Japanese manufacturing, to a "Partnering Chain Management System on Platforms", as well as to establish the method of this system's operation.

3. Science TQM, A New Quality Management Principle

In this chapter, a "new principle of next generation TQM - Science TQM", will be proposed, and its validity will be demonstrated. Science TQM systematically and organizationally contributes to the solution of management technology problems by capitalizing on the "new quality control principle, Science SQC" and a "Strategic Stratified Task Team".

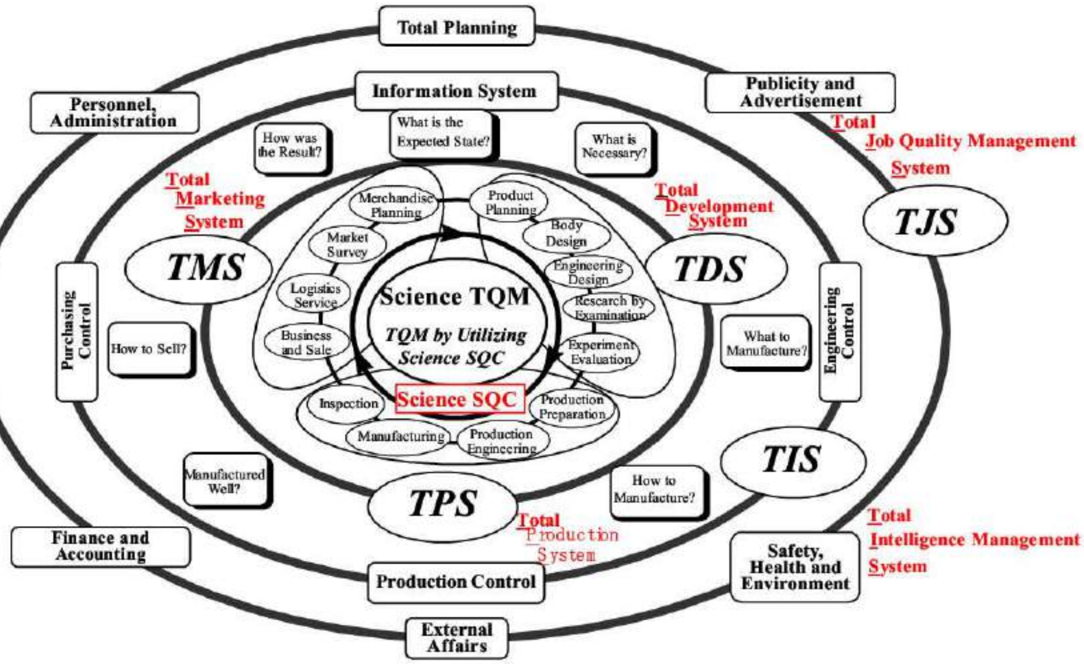


Figure 2. Science TQM, A New Quality Management Principle

3.1 The Proposal of Science TQM, A New Quality Management Principle

The goal of TQM activities in manufacturing is to offer attractive products. Therefore, in order to reform the foundation of TQM activities and keep pace with the changing times it is necessary to implement "Customer Science" [14]. To implement this it is vital for all departments to share the same values toward work and improve the quality of their work through cooperation. More specifically, a new principle of TQM will be needed that can establish the factors for reasonable management technologies and link them together.

In recent years however, the concept of quality has been expanding to include not only product quality, but also the quality of the business process and even that of corporate management. In step with this trend, the scope of TQM activities has also become more wide-ranging. Therefore, the generators, mentors, and promoters of TQM have had a hard time managing every single technique and skill of all the individuals belonging to different positions or departments, as well as the technology related to workplace management (workplace formation). This is because the existing TQM activities are based on past successes brought about by each person's particular experience or skills, and this is not enough to encompass all the new diversified technologies, such as those mentioned above.

In order to create customer-oriented, attractive products that can truly satisfy the customer's demands, a core technology needs to be established. This technology would allow the (1) technological development designing, (2) production engineering and manufacturing, and (3) the advertising, promotion, and sales-related departments, to be organically linked together by (4) the management department, and (5) the personnel and general administration departments. These departments have the role of effectively utilizing human resources in all of the other departments in order to activate the organization and to improve the quality of their work. It is imperative that all these departments are linked with one another systematically and organizationally.

Therefore, a new quality management principle - Science TQM [3] is hereby proposed and illustrated as shown in Figure 2. This is a new principle of TQM which links and rationalizes the business process of each department into a continuous circular ring in order to grasp the mission of each department involved in management technology. It is composed of five core principles, namely: (1) the Total Development System, TDS, (2) the Total Production System, TPS, (3) the Total Marketing System TMS, (4) the Total Intelligence Management System, TIS, and (5) the Total Job Quality Management, System, TJS. This ensures that each department is equipped with the core technology and is linked to the others.

3.2 Science SQC, The Key to the Strategic Development of Science TQM

The main focus of Science TQM is to strategically utilize Science SQC [15-16] in order to strengthen the core technology and to have it contribute systematically and organizationally to the activities of QCD, CS (Customer Satisfaction), ES (Employee Satisfaction), and SS (Social Satisfaction). To achieve these management tasks, it is important for all divisions to turn the implicit knowledge of their business processes into explicit knowledge through integrated and collaborative activities and sharing objective awareness.

To accomplish this, Science SQC, a new quality control principle was proposed by the author and developed under a new concept using a new methodology that applied the four core SQC principles in order to enable work to be performed scientifically as shown in Figure 3.

The first of the four principles, "Scientific SQC" is a scientific approach, and the second principle, "SQC Technical Methods", is a methodology for problem solving. The third principle, the Integrated SQC Network, which is called "TTIS" (Total SQC Technical Intelligence System), is designed to turn management technologies that deal with proprietary technologies or business processes into owned assets. The fourth principle, "Management SQC", interprets the gap between the theory and reality of technical problems as the problems existing between departments and organizations. It then verbalizes the implicit understanding inherent in the business process in order to present it as explicit knowledge and also as a general solution to the technical problems.

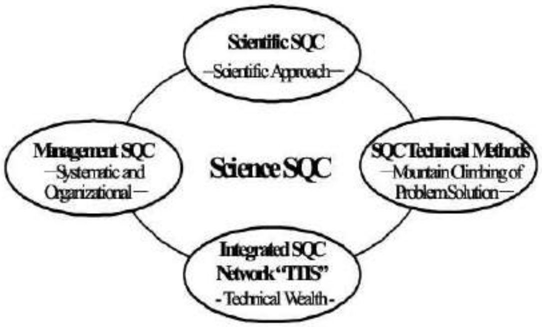


Figure 3. Outline of Science SQC

Science SQC takes a scientific approach to work operations based on these four principles, and is not limited to an "individual solution", which only provides a special or partial solution to the problem. Rather, it is a new principle that describes a next generation quality management technique for the manufacturing business. It aims to provide a universal "general solution" and thereby create a new technology for problem solving.

3.3 A Strategic Stratified Task Team, the Driving Force Behind Science TQM

In addition as a management technology strategy that enables sustainable growth, the author [3] has proposed a "Strategic Stratified Task Team" that will become the driving force of Science TQM. This is shown in Figure 4.

The expected role of the strategic stratified task team and the benefits it will provide are not limited only to cooperation among the departments inside the company. It will also contribute to the strengthening of the ties among group manufacturing companies, non-group companies, and even overseas manufacturers. Two measures must be taken in order to realize this proposal. First, is eliminate cast the work methods that rely too heavily on the techniques and experiences of individuals. Second, is to revolutionize the business process through the proposed "structural model of a stratified task team (Task 1 to Task 8)" that places emphasis on cooperation among the departments, with suppliers, and others.

As the technology level involved expands to include higher strata, for example moving from Production Strategy I to Production Strategy II, and from to Quality Management Strategy I to Quality Management Strategy II, the structure of the task team extends its boundaries (cooperation) upward starting from the level of groups/sections, to divisions/departments, to the entire company, and finally to suppliers (group companies, non-group companies, and overseas companies).

4. Development of Science TQM for the Evolution of Management Technology

Having said the above, in this chapter the five core principles of TDS, TPS, TMS, TIS, and TJS will be established and integrated for the purpose of strategically realizing the deployment of Science TQM that is necessary to carry out the innovation of management technology.

4.1 Strategic Integration of the Five Core Principles -TDS, TPS, TMS, TIS and TJS

In order for the principle of Science TQM proposed by the author to contribute to the permanent innovation of management technology, it is essential to organically integrate the five core principles and strategically link the business processes in each department in a highly cycled manner as shown in Fig. 5. [17]

More specifically, as illustrated in Fig. 6, it will be vital to collect and analyze product quality information gathered from outside and inside the company. Then use this information to create "wants" as part of the market creation activity and also to establish a structure for development and production that is capable of offering new products. [18]

In the implementation stage, it is important to apply Science SQC and Science TQM, via a verifiable scientific business approach, to each step ((1) Input information, (2) Information for development, and (3) Output information) of the business process of development designing and manufacturing. This is done in order to effectively carry out the strategic integration of the five core principles and also to bring about the evolution of management technology that can ensure high reliability.

By means of the synergy effect generated through the linkage cycle for improving the business process improving, it is expected that a universal technological solution method can be established to replace the "individual solutions" created from the accumulation of partial solutions.

4.2 Establishment of the Five Core Principles

4.2.1 The First Core Principle – TDS

Taking a close look at recent product recall incidents, it is clear that a crisis in reliability is rapidly arising from the areas of technological development and design evaluation. What is required is not simply the solution to a single separate technological problem, but the creation of a core technology that will lead to the reform of the whole business process for technological development, as well as the establishment of a core technology that will also improve "human reliability".

The main focus of the first principle, TDS is, as seen in Figure 5, to promote the "sharing of information" by incorporating the four sub core elements (a) to (d), and to make possible "the creation of the latest technology" and "optimal designing" in response to the advancement of technology. The required technological elements are, (a) designing based on internal and external information that places priority on the design philosophy, (b) development design

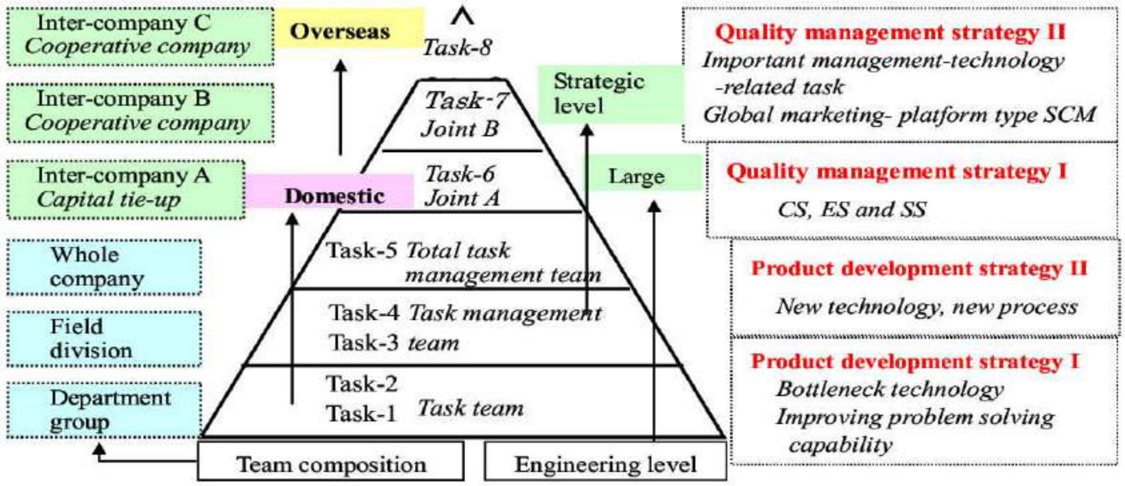


Figure 4. Structured Model of Stratified Task

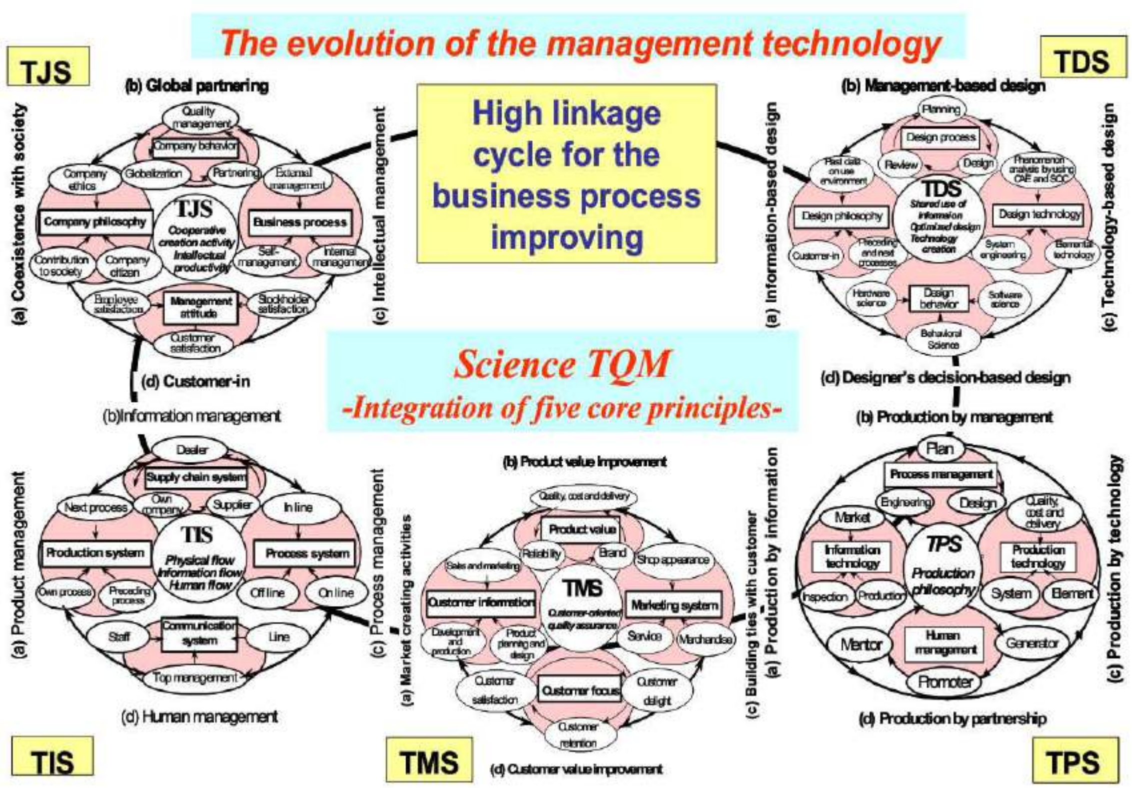


Figure 5. Science TQM Strategy Using Integration of the Five Core Principles

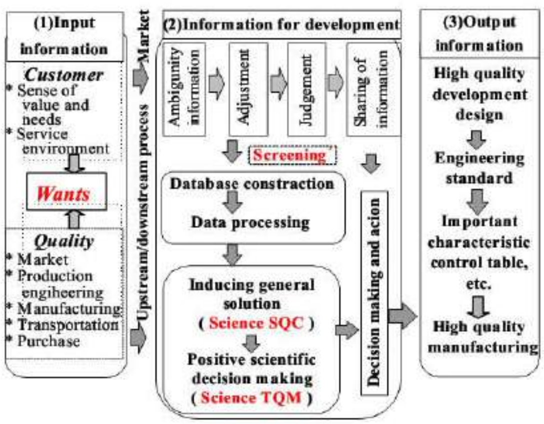


Figure 6. The Business Process of Development Design and

management aiming to achieve a rational design process, (c) creation of a design method that incorporates the latest design technology in order to obtain universal solutions (general solutions), and (d) systemization of the development design management method to clarify and set the design policy of the development designers (theory → action → decision-making).

4.2.2 The Second Core Principle – TPS

In the midst of the recent drastic changes in manufacturing methods caused by the introduction of digital engineering, it is vital to reconstruct a world-leading, next generation production management technology so that the core part of manufacturing does not lag behind the "advancement of production management".

The main focus of the second principle, TPS is, as seen in Figure 5, to enable the strengthening and enrichment of "customer-oriented, employee-focused, process management". This is done by incorporating the four sub core elements (a) to (d). The required technological elements are, (a) innovation to introduce a customer-oriented production management system that puts the highest priority on the quality of information obtained from inside and outside the company, (b) creation of a rational production process and management of its workplace implementation, (c) QCD study activities using the latest production technology, and (d) creation of an active workplace environment which is able to manage the partnership proactively.

4.2.3 The Third Core Principle – TMS

As more and more emphasis is given to CS, CD (Customer Delight), and CR (Customer Retention), the advertising and promotion, sales, and service departments are expected to play new roles. What is necessary is the kind of marketing activity that is not merely based on past experience, but which promotes the strengthening of ties with the customers, the building of reliability into the products or corporate activities, and gathering information that will be helpful in the creation of next-generation products. This will be the basis for quality management activities in the future.

The main focus of the third principle, TMS, is, as seen in Figure 5, to enable "customer-focus, customer value creation, and high quality assurance". This is done by incorporating the four sub core elements (a) to (d). The required technological elements are, (a) market creation activities through gathering and utilizing customer information, (b) improvement of the product value through understanding the vital elements that will enhance this value, (c) establishment of a marketing system from the standpoint of creating trusting ties with the customer, and (d) the creation and enforcement of a code of corporate conduct to increase the customer value and continually improve customer satisfaction.

4.2.4 The Fourth Core Principle – TIS

The management department is the core of corporate activity and therefore it is vital for it to reinforce the functions of "business management technology" so as to strengthen and enrich both internal and external management. This is also done in order to create a business linkage with the general administration department and cooperate with the on-site departments, such as development designing, production, and sales departments, as well as with business partners.

The main focus of the fourth principle, TIS, is, as seen in Figure 5, to enable the strategic implementation of JIT (Just in Time) for the business flows involving human resources, technical information, and product information. This is done via the utilization of intelligent information, so as to establish a new quality management technology system that incorporates the four sub core elements (a) to (d). The required technological elements are, (a) the product management system, in which the pre-process and post-process are integrated, (b) the intelligent information management system, which combines the dealers and suppliers, (c) the knowledge-intensive type total business process management system, which connects the congested off-line, in-line, and on-line process systems, and (d) the communication management system, which improves human management as the basis for the integration of the cooperative activities participated in by the top line staff.

The mission of the management department is to accurately handle the current issue of "global production - worldwide simultaneous production and production at optimal locations", so as to realize the so-called, "worldwide quality competition - simultaneous achievement of QCD".

4.2.5 The Fifth Core Principle - TJS

It is increasingly important for the general administration-related department to advance corporate management by grasping the changing domestic and overseas environment surrounding the industry. It should also cooperate with the management department so as to strengthen internal and external management. In order to achieve this, it is urgently necessary to position human resource development at the core of management policy in order to enhance "corporate, organizational, and human reliability" as the basis of strategic quality management. It is also necessary, at the stage of utilizing human resources, to strengthen the function of improving intelligent

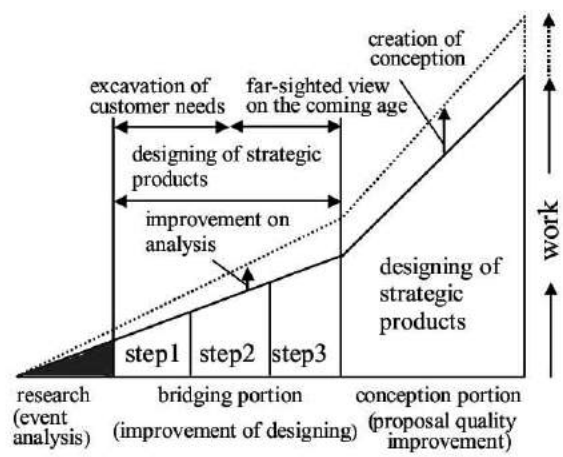


Figure 7.Automotive Profile Design Methods

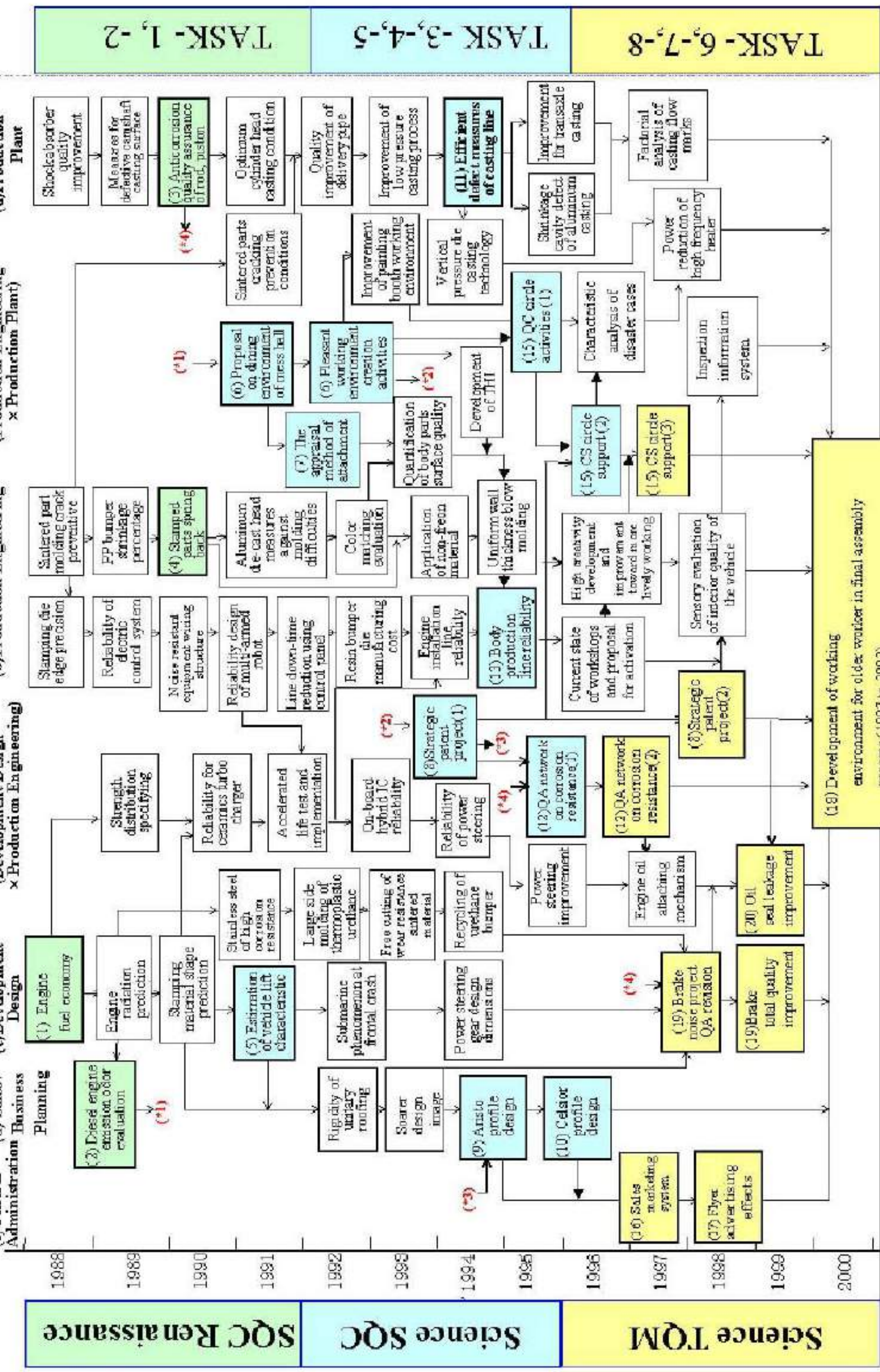
productivity through cooperation with all the related departments.

Having said that, the main focus of the fifth principle, TJS, is to produce substantial results from the process of "improving intelligent productivity - cooperative activity - human resource development". This is done through cooperation with the development designing, production, customer and sales, and management-related departments. It also involves, as seen in Figure 5, the establishment of an "intelligent productivity improvement business model" that is able to solve pressing problems inside and outside the company by incorporating the four sub core elements (a) to (d).

The behavioral code for the general administration-related department, which involves the "corporate philosophy, corporate behavior, and business process management attitude", has been designed to totally link the four sub core elements. These elements are, (a) coexistence with the society, (b) global partnering (c), intelligent management, and (d) customer-in. This code will then be turned into a model and put into effect.

As discussed above, these five core principles are implemented in order to combine the intelligence of all departments utilizing the Strategic Stratified Task Team activity and to apply Science SQC via a verifiable scientific business approach as the high linkage cycle for improving the business process [3-4].

Table 1. Changes in the Strategic Task Team Activities of Toyota (1988-2000)



5. Application - Putting into Practice and Verifying the Validity of Science TQM at Toyota

In this chapter, the author introduces a few study examples of how Science TQM improved the management technology at an advanced corporation, Toyota, and also at Toyota Group companies and others.

5.1 Transition in and Validity of the Strategic Joint Task Team Activities

In this section, the author will introduce the transition and validity of Science TQM through the Strategic Joint Task Team Activities in order to advance the evolution of management technology. In concrete terms, the author proposed and developed the formation of Strategic Stratified Task Teams (Task-1 to 8) as seen in Figure 4, and the validity of these task teams was verified through their application within Toyota and Toyota Group companies [3].

The author was in charge of promoting strategic quality management, and therefore organized and led the task teams. The task teams tackled various engineering issues. Table 1 is a chart of the activity themes that were undertaken and accomplished by the task teams. From 1988 to 2000, about 15,000 staff and 5,000 managers carried out 4,000 task team activities. Some of these activities were later presented to Japanese and overseas academic organizations in the form of theses.

The table covers about one-fifth of all those activities.

Corporate divisions such as (a) production plant, (b) production engineering, (c) development design, (d) sales and business planning, and (e) general administration are arranged in the horizontal direction. An "×" in the table is the symbol for cross-divisional collaboration, while an arrow means that the technical findings obtained from an activity were passed on to the next study (handing down of technologies). Tasks are stratified vertically from the top: (1) Task-1 (small group level) and Task-2 (group and department level) task team activities were part of the "SQC Renaissance" (1988 on) (Refer to Appendix A). In the middle are (2) Task-3 (division level) and Task-4 (field level) task team activities that were part of Science SQC (1992 on). At the bottom is (3) Task-5 (across different fields and companies), task team activities that were part of Science TQM (1996 on).

Furthermore, the table also includes (4) Task-6, "joint total task management team" activities in which Toyota collaborated with group manufacturers, (5) Task-7, team activities with non-group manufacturers, and (6) Task-8, team activities with overseas manufacturers. The table indicates how the technical themes organizationally and systematically evolved from Task-1 to Task-8, thereby enhancing the level of the strategies employed.

5.2 Validity of the Five Core Principles

5.2.1 The Effectiveness of TDS

Two of the study examples that contributed to the establishment of TDS, the core technology of development designing are: (i) the business process method for "Automotive Profile Design Methods" [19] as shown in Figure 7, to support the designer's conceptual process, and (ii) the application of advanced and accurate CAE for the "Prediction Model of Automotive Dynamic Lift Characteristics" [20] that shortened the period needed for highly reliable designing and development. Moreover, through the cooperation of the development designing, production, sales, service, and purchasing procurement departments with the suppliers, (iii) the failure mechanism of such worldwide technical issues as "Brake Squeal" [21], and the (iv) "Oil Leak in the Drive-train Oil Seal" [22], were also clarified.

Then, by utilizing the acquired technical results for improving the prediction accuracy of (v) the CAE numerical simulation [23], a substantial quality improvement was

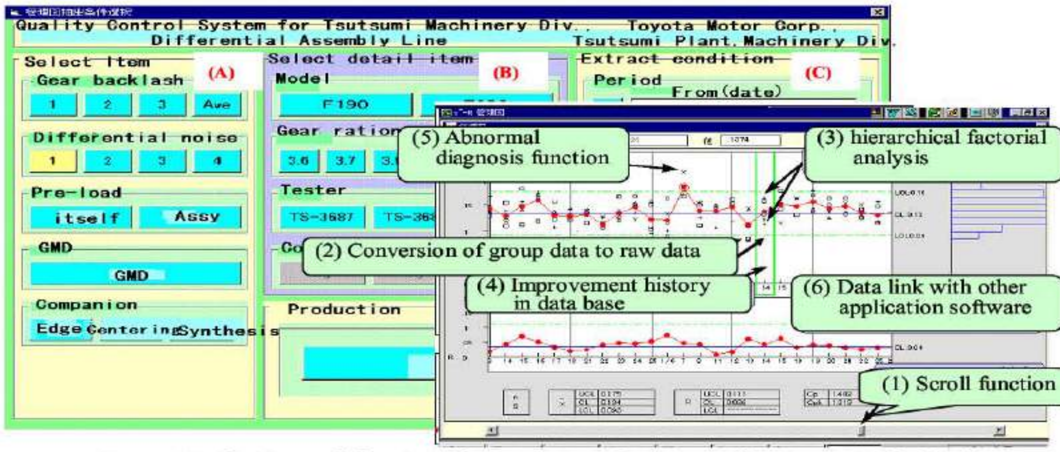


Figure 8. Outline of Control Chart using Software System, TPS-QAS

successfully achieved. All of these are the results of the "Strategic Joint Task Team Activities", in which the top management assumed the leadership role in finding the solution to the management technology issues. Through company-wide partnering with both the Toyota Group and non-group supplier manufacturers, QCD was simultaneously achieved and the strategic innovation of quality management was realized [7, 24-25].

5.2.2 The Effectiveness of TPS

Two of the study examples which contributed to the establishment of TPS, the core technology for production engineering and manufacturing are: (i) the implementation of the global production compatible, "TPS-QAS, -Quality Assurance System" [26] as shown in Figure 8 and (ii) the "facility operation, maintenance management system - ARIM-BL" [27], in which TPS and IT are intelligently integrated by making full use of intelligent "In Line-On Line SQC".

Another example is (iii) the next generation "innovation of the work environment" [28] through collaboration among all departments. In this activity, all the departments related to safety, health management, and human resource development cooperated together in a program to improve the working environment. This program, called "AWD-6P/J" (Aging & Work Development 6 Programs Project), was promoted to make the work environment more accommodating to older workers and female workers. The expected results have been achieved through arranging the on-site automotive assembly shops to accommodate older employees, who are being actively deployed in the production plants inside and outside of Japan.

Furthermore, in order to realize (iv) the key to success in "global production" - "uniform quality and simultaneous plant start-up

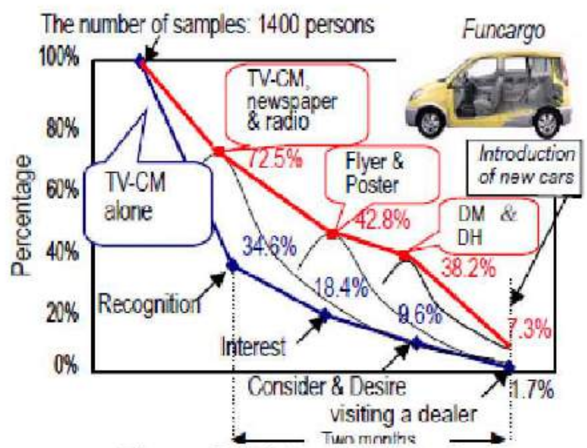


Figure 9. Mixture Effect of Advertisement Promotion

worldwide (production at optimal locations)", the manufacturing, production engineering, production management, and information system-related departments are currently collaborating with one another, and results are being obtained in which the previously acquired results are being integrated and further developed [29-30].

5.2.3 The Effectiveness of TMS

One of the study examples that contributed to the establishment of TMS, which is the core technology of sales, advertising, and promotions-related departments is: (i) the implementation of the "Toyota Sales Marketing System" [31] that aims to improve the "formation of ties with the customer".

Through scientific verification of the customers' purchasing patterns, (ii) the mixture effect of advertising promotion, consisting of TV commercials, newspaper ads, radio ads, flyers, and DM/DH (direct mail/direct handing), was enhanced to raise the rate of customers' visits to automobile shops, as well as to realize "market creation" [32] as shown in Figure 9. (iii) "Market creation" in this sense means the reform of the (dealer) shop front advertising and promotions, sales, and customer services, so that the expected results can be successfully achieved [33].

5.2.4 The Effectiveness of TIS and TJS

Study examples that contributed to the establishment of TIS are: (i) the creation of "HI-POS" (Human Intelligence–Production Operating System) that cultivates "highly skilled, intelligent production operators" capable of handling the advanced production system. After realizing high quality assurance, the improvements in the production facility operating rate or innovation of the facility maintenance system through (ii) the application of "V-MICS" (Visualization - Maintenance Innovated Computer System) as shown in Figure 10 have been promoted [34]. The establishment of (iii) the "TPS-LAS" (Process Layout Analysis Simulation) has been promoted as typified by the "optimization" of the entire production plant and formulation of the production process, including the work operators, robots, logistics, and delivery, by making full use of CAE numerical simulation [35].

A fourth example is (iv) where the purchasing procurement, production management, TQM promotion, and quality

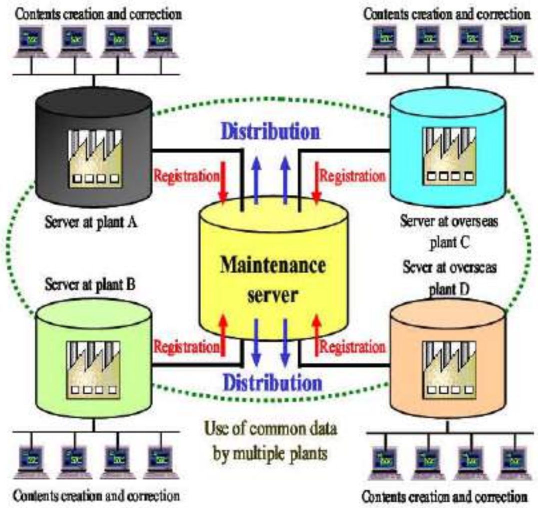


Figure 10. Hardware System for V-MICS-DB

assurance-related departments constitute a core, and then cooperate with the technical management, production engineering, production management, manufacturing inspection, and sales promotion-related departments [36]. In this way (v) "Partnering Chains on a Platform Basis" have been established collaboratively as the basis of the quality management system "CS-CIANS" (Customer Science utilizing Customer Information Analysis and Navigation System) in systematic and organizational cooperation with supplier manufacturers [19]. Through this activity, (vi) the establishment of a "Quality Management Strategy Model" necessary for the "strategic simultaneous achievement of QCD" with Toyota Group and non-group manufacturers is also being developed [17,37].

Similarly, study examples that contributed to the establishment of TJS are: the establishment of the (vii) "Knowledge Management System" to convert intelligent technologies into the form of assets so that they may be passed on to future generations and further developed. This was accomplished through cooperation among the technical management, intellectual property, production engineering, TQM promotion, and personnel affairs-related departments.

One example of this system is (viii) the development and operation of the "Quick Registration and Retrieval System for Technical Reports, TSIS-QR" [38 and the

"SQC Integrated Network System" [25] in which Science SQC was incorporated and the priority management technology issues were solved. Other examples are the development and operation of the (ix) "Patent Value Evaluation Method" [39], a business model for strategic patent creation, and (x) the quality management assessment business model, "Measurement System for Strategic Quality Management Performance" [40].

5. Conclusion

In this paper, a new, next-generation quality management principle, Science TQM verified through the demonstrative study examples undertaken at an advanced corporation, Toyota. Recently, the creation of new management models is being demanded to achieve a significant leap forward in the Japanese style of quality management and this new principle can serve as just such a model. At the present, Science TQM, the principle proposed by the author, is now going through a verification process to prove its validity in many other advanced Japanese companies. This is being done in order to deploy and establish it as the "*New Japan Model*" that is expected to help realize strategic quality management [4].

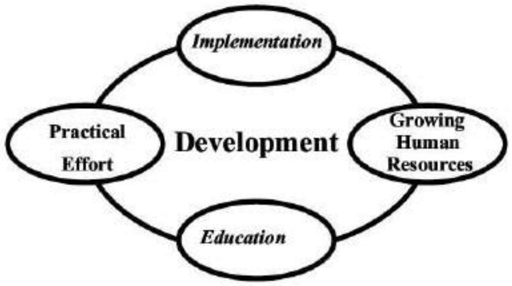


Figure A. SQC Promotion Cycle Activities

Appendix A: The SQC Renaissance

The author has been engaged in *SQC promotion cycle activities* (Implementation – Practical Effort – Education – Developing Human Resources) under the banner of the SQC Renaissance, as shown in Figure A. This was done in order to capture the true nature of making products and in the belief that the best way to develop personnel is through practical research that will raise the technological level. The aim of SQC that is being promoted by Toyota is to take up the challenge of solving vital technological assignments [23].

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A Framework for Risk Management in New Global Business Ventures

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Abstract

A robust, replicable framework for managing risks in new global business ventures is provided by integrating the methodology developed by the United Nations Industrial Development Organization (UNIDO) for preparing industrial feasibility studies with Boehm's spiral-modeling approach for software development. This incorporates a qualitative model for risk assessment to facilitate the risk/return tradeoff associated with investment decisions. We illustrate the application of this framework to facilitate risk identification and mitigation in a new global business venture in the Caribbean.

Keywords: *Risk Assessment, Feasibility Study*

1. Introduction

Global business has become increasingly important to companies as foreign competitors increase their market share in other markets, and emerge as essential sources of low-cost products, technology, and financial and human capital. [1]. This competitive environment presents challenges for managing the risks associated with new business ventures which can be located almost anywhere in the world. The risk and uncertainty posed by factors such as the political instability of the region selected for the venture's location and the inadequacy of the infrastructure associated with a particular site, need to be considered along with the more traditional risks associated with market, technology and financial factors to ensure that appropriate risk mitigation strategies are developed.

Techniques proposed for risk management on new ventures include expert systems [2], simulation modeling [3], decision analysis [4], scenario planning [5], and information systems [6]. The literature provides several case studies of the application of these risk management techniques [7], [8], [9] and reports general consensus on the steps required in risk management viz. risk identification and risk mitigation. However, there have been limited efforts to develop a robust replicable risk management framework to facilitate the explicit risk/return tradeoff associated with investment decisions.

In this paper, we provide a robust, replicable framework for managing risks in new global business ventures by integrating the three-stage methodology developed by the United Nations Industrial Development Organization (UNIDO) [10] for preparing industrial feasibility studies with Boehm's four-phase spiral-modeling approach [11] for software development. A case study is used to illustrate the application of this framework to facilitate risk identification and mitigation in a new business venture in the Caribbean.

2. Risk management techniques

As shown in Table 1, the wide range of techniques used for risk management can be grouped into three broad categories: *Management Science, Artificial Intelligence (AI), and Other*. Among the Management Science techniques, *Simulation* was used frequently [3], [12], [13] enabling analysts to quantify the uncertainty inherent in new ventures by developing a probability

Table 1: Evolution of risk management techniques

			Mgmt. Science			Artificial Intelligence					Other				
Year	**Study**	**Focus**	**Simulation**	**Dec. Analysis**	**MCDM**	**PMKES**	**Expert Sys.**	**ANN**	**ANN/ES**	**Fuzzy-Logic**	**Info Systems**	**Quantitative**	**Qualitative**	**Proprietary**	**Risk Model**
1983	Liberatore & Titus	R&D	x												
1984	Johnson	Public Admin.											x		
1987	Ramachandran	Audit											x		
1988	Foster	Project Mgmt					x								
	Lenss	Project Mgmt					x								
1989	Bowen & Erwin	Construction					x								
1990	Campbell & Rankin	Audit										x			
	Chepurnix & Miresco	Construction					x								
1991	Curley & Meyer	Technology					x								
	Rahbar *et.al.*	Construction				x									
	Singh	Construction					x						x		
1992	Woodhead	Audit													x
1993	Das	Project Mgmt													
	Kuklan	Project Mgmt													
	McKim	Construction						x							
1995	Kanter & Pitman	Audit													x
1996	Dey & Tabucanon	Petroleum									x				
	Lynn & Murray	TQM					x								
1998	Al-Jaroudi	Telecom			x										
	Dawson & Dawson	Project Mgmt													
	Liu	Oil and Gas						x							
1999	Al-Tabtabai *et.al.*	Construction					x	x							
	Back & Insidore	Construction	x												
	Bailey *et.al.*	Audit						x							
	Balcombe & Smith	Capital Budg.	x												
2000	Austin *et.al.*	Construction									x				
	Chen & Hartman	Oil and Gas						x							
	Dusenbury	Audit													x
	ISACA	IS									x				
	Joshi	Construction													
	Wong	Audit				x									
2001	Datta & Mukherjee	Steel									x				
	Knight	Construction								x		x			
2002	Bedard *et.al.*	Audit												x	
	Brown & Todd	IS							x						
	Dey	Construction		x	x										
2003	Ahsan & Tsao	Project Mgmt				x									
	Becker *et.al.*	Audit						x		x					
	Jaafari & Yao	Capital Budg.		x											
2004	Amescua *et.al.*	IS									x				
	Kumaraswamy *et.al.*	Construction									x				
	Lefley	Capital Budg.											x		
	Nozick & Turnquist	IS										x			
	Skorupka	Technology						x							
2005	Anderson & Joglekar	Automotive											x		
	Levin & Rad	Capital Budg.									x				
	Liberatore *et.al.*	Project Mgmt	x												
2006	Ahmad *et.al.*	IS												x	
	Allen *et.al.*	Audit													x
	Aramvareekul et al	Project Mgmt											x		
	Colbert & Weirich	Audit													x
	Francis & Miresco	Construction											x		
	Ganesh et.al.	Infrastructure	x										x		
	Hillson & Hulett	Portfolio Mgmt		x											

distribution of possible investment outcomes. Decision trees and multi-criteria models have also played an integral part in risk mitigation. One particular study sought to capture the combination of these two approaches to quantify risk in construction projects [14].

Several *Artificial Intelligence* techniques have been deployed to aid risk mitigation. Expert systems have been used to capture the expertise and proficiency attained by industry practitioners within a specific domain in order to identify and mitigate risk in projects [15], [16]. Artificial neural networks have also been used to replicate the thought process of a project manager or a domain expert [17]. The ability of this technique to mimic the decision making of professionals makes it a vital tool for risk recognition and reduction [18]). Other AI techniques used for risk management include Project Management Knowledge-Engineering Systems [19], [20], hybrid Expert Systems/Neural Networks [21], and Fuzzy Logic [22].

Other risk management techniques reported in the literature include Information Systems (IS) and qualitative, quantitative, and proprietary models. One interesting proprietary model is KRisk [23] developed by KPMG LLC which offers a good example of efforts by practitioners to create a framework that captures the essence of risk assessment and risk reduction. Other IS-based risk management techniques are Decision Support Systems [24] and Entity-Relationship diagrams [25]. These approaches graphically display the processes related to risk identification and risk mitigation.

The following section describes a framework proposed to integrate these techniques into a robust and replicable methodology which would enable companies to identify and manage the risks associated with the establishment of new global business ventures.

3. Risk management framework

The framework proposed for risk management on new global business ventures is summarized in Figure 1. Here, as proposed in the UNIDO methodology [10], evaluation of the new venture proceeds through the

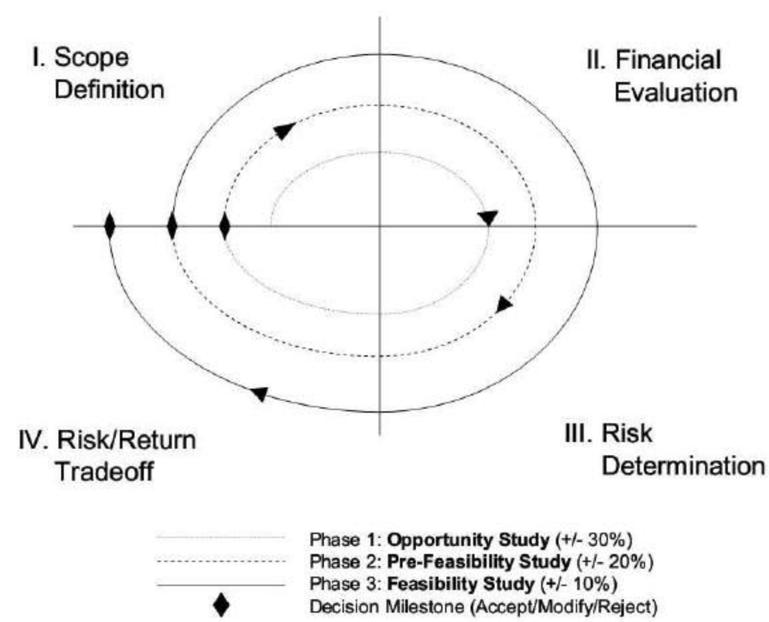

Figure 1. Proposed risk management framework

three stages of an Opportunity Study, Pre-Feasibility Study, and finally Feasibility Study with each stage providing an increasing level of detail and accuracy in the input parameters used to analyze the project. A review is conducted at the end of each stage and a management decision is made to accept, modify, or abort the new venture. Each stage advances in a cycle of four phases viz. *Scope Definition, Financial Evaluation, Risk Determination,* and *Risk/Return Trade-Off.* In the final phase of each cycle, *Risk/Return Trade-Off,* a qualitative risk model is used to facilitate risk classification of the new venture and facilitate logical risk/return tradeoff decision making.

In each cycle, the steps required for risk management in new global ventures are as follows:

Step #1: Define the project scope

Step #2: Compute the project's weighted average cost of capital (WACC)

Step #3: Compute the project's internal rate of return (IRR)

Step #4: Determine project's risk classification

Step #5: Determine project's hurdle rate (Hurdle Rate = WACC + risk premium)

Step #6: Make investment decision, i.e.
If IRR > Hurdle rate, accept and proceed to the next stage

If IRR = Hurdle rate, modify and review

If IRR < Hurdle Rate, reject and terminate the project

When implementing this framework, analysts may encounter several challenges. These include determination of a company's WACC which can be a very difficult task for global ventures [26]. Another challenge can occur when the stream of cashflows has more than one change in signs thus resulting in multiple rates of return, none of which is correct. [27], [28]. In such cases, an External Rate of Return (ERR) [29] can be used to manipulate the cashflows to enable only one change in the sign of the cashflows and thus yield a unique Internal Rate of Return. The following section describes a case study to illustrate the application of this framework to facilitate risk management on a new global business venture.

4. A case study - Caribbean deluxe hotel and convention center

4.1. Phase #1 - Scope Definition

A consulting company based in North Florida was engaged to assess the viability of establishing a new deluxe hotel and convention center (DHCC) in the Caribbean. The DHCC would assist in accommodating the large influx of tourists expected for the 2007 Cricket World Cup tournament and would operate thereafter as a preferred venue for conventions. In the initial stage, the company established the following design parameters for the proposed facility:

- 300 room facility
- Deluxe single, double and suite rooms
- Lobby, restaurants, and bar
- Conference rooms
- Convention and banquet facilities
- State-of-the-Art technology and business center
- Sports center including equipment, dressing rooms, showers, sauna and swimming pools
- Security
- Later addition of a casino

Table 2 summarizes the three stages in the development of the proposed business venture using the UNIDO methodology for evaluating new investments. This paper focuses on the *Opportunity Study*, the first stage in the process. However, successful project implementation would require the business venture to proceed to the Feasibility Study stage in which a specific construction site must be identified and more accurate estimates obtained for cashflow forecasts based on more detailed analysis.

Table 2: Stages in development of new global business venture

Development Stage	**Location of Venture**	**Estimating Accuracy**	**Effort (man-mths)**	**Cost of Study ($US) (% of Project Costs)**
Opportunity Study	Caribbean Region	+/- 30%	2 – 3	$US20K – 100K (0.2 – 1.0%)
Pre-Feasibility	Caribbean Island	+/- 20%	6 - 12	$US25K – 150K (0.25 – 1.5%)
Feasibility	Site	+/- 10%	12 - 15	$US100K – 300K (1.0 – 3.0%)

The *Opportunity Study* incorporated the following activities:

- **Location Study** to assess the suitability of eight English speaking Caribbean countries as venues for the new facility.
- **Market Analysis** to gauge the market need for the services to be provided by this type of Facility
- **Financial Evaluation** to provide a preliminary assessment of the risks and returns associated with this project

4. 2. Phase #2 - Financial Evaluation

A financial model was created to provide a baseline view of the new venture's expected cash flows. Table 3 provides a summary of the cash flow forecasts for the construction and operation of a hotel/conference center located in the Caribbean. Using this deterministic model, the financial indices associated with this venture are:

- Net Present Value at an interest rate of 12% per annum of $3.4 Mn
- Internal Rate of return of 16% per annum
- Payback Period of 9 years

These results show that the new venture could be profitable, However, the relatively long payback period, although typical of hotel construction projects, would suggest that careful consideration be given to risk determination in the next phase of the evaluation of the venture.

4.3. Phase #3 - Risk Determination

Preliminary assessment of the risk and uncertainty associated with the project was done using:

- *Sensitivity Analysis* to show the effect of incremental changes to several aspects of the venture's cash flows on the Net Present Value of the project.
- *Scenario Analysis* to consider alternative investment outcomes in the best case, worst case, and most likely scenarios.
- *Simulation Modeling* to develop a probabilistic financial model to calculate the probability of an unprofitable venture.

The sensitivity analysis examined the impact on Net Present Value of variations of +/- 30% in the following parameters:

- Revenue from Room Rentals
- Other Revenue
- Operating Costs
- Marketing Costs

Figure 2 provides a summary of the results of the sensitivity analysis. The spider plot of these results showed that the project was very sensitive to changes in project parameters with changes in revenues from room rentals

Table 3: Summary of cashflows ($US '000) for deluxe hotel and convention center in the Caribbean

		Construc-tion		Operation										Terminal Value
	Year	*2006*	*2007*	*2008*	*2009*	*2020*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
CASH INFLOWS	***Param -eters***													
Capacity (# of Rooms)	***300***													
Occupancy Rate (%)	**1.00**			50	55	60	65	65	70	72	74	76	78	
Room Rate ($/day)	***150***													
A1: Room Rentals Revenues	***1.00***			8213	9034	9855	10676	10676	11498	11826	12155	12483	12812	
A2: Food & Beverages	***0.30***			2464	2710	2957	3203	3203	3449	3548	3646	3745	3843	
A3: Other Revenues (%)	***1.00***			40	45	50	55	60	65	70	70	70	70	
Other Revenues ($)				3285	4065	4928	5872	6406	7473	8278	8508	8738	8968	
A. TOTAL CASH INFLOWS				13961	15809	17739	19751	20285	22420	23652	24309	24966	25623	25000
CASH OUTFLOWS														
B3: Initial Investment Outlay	***58000***													
B.1.1 Equity (Land Acquisition)	***0.08***	4,350											-4350	
B.1.2 Development Financing	***0.05***				2900	2900	2900	2900	2900					
B.1.3 Mortgage Repayment	***0.07***				4060	4060	4060	4060	4060	4060	4060	4060	4060	
B.1.4: Suppliers' Credit	***0.06***				3480	3480	3480	3480						
B.1.5 Bank Repayment	***0.04***			2320	2320	2320								
B5. Operating Costs	***1.00***	50%		4106	4517	4928	5338	5338	5749	5913	5470	5617	5765	
B6: Marketing Costs	***1.00***	20%		2792	3162	3548	3950	4057	5605	6623	6807	6990	7174	
B7: Corporate Tax Paid	***50%***			631	1165	1732	2331	2545	2633	2658	3116	3279	3442	
B. TOTAL CASH OUTFLOWS		4,350	0.0	9850	21604	22967	22060	22380	20947	19254	19453	19947	16091	2500
C. NET CASH FLOWS		-4350	0	4111	-5795	-5228	-2309	-2095	1473	4398	4856	5019	9532	22500
Cumulative Net Cash Flow		-4350	-4350	-239	-6033	-11262	-13570	-15665	-14192	-9794	-4937	82	9613	32113
Discount Factor (i=12% p.a.)	***12%***			1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.3220
Disc. Cash Flows(i =12% p.a.)		0	0	4111	-5174	-4168	-1643	-1331	836	2228	2197	2027	3437	7244
Cumulative Disc. Cash Flow		0	0	4111	-1063	-5230	-6874	-8205	-7369	-5141	-2944	-917	2520	9765
D. FINANCIAL INDICES														
Payback Period (years) =	**8.98 yrs**		**Disc. Payback Period (years) = 9.36 yrs**					**NPV @ 12% p.a.**		**= $3,434,298**			**IRR (%) =**	**16% p.a.**

having the greatest impact on the net present value of the project. Relatively small decreases in the marketing and operating costs can also yield large increases in the net present value.

The results of the scenario analysis summarized in Table 4 show the Payback Period, Net Present Value, and Internal rate of Return of the venture under the best, most likely, and worst case scenarios. This analysis reveals that the venture had a modest upside but an unacceptable downside.

The simulation model constructed to incorporate probabilistic inputs into the financial model generated a probability distribution of the Net Present Value based on 1000 iterations of the model. In this case, subjective probability distributions were assigned to the streams of revenues and disbursements and a simulation analysis was conducted using the Crystal Ball software, an EXCEL "add-in" for advanced analysis with spreadsheets [30]. The probability distribution of the venture's Net Present Value shown in Figure 3 indicated that the probability of the project returning a negative net present value was less than 10%.

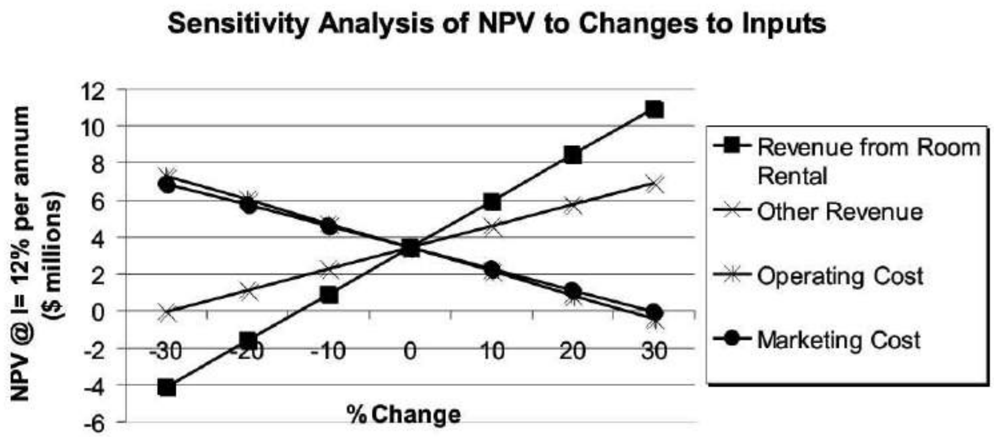

Figure 2: Spider plot of results of sensitivity analysis

Table 4: Results of scenario analysis

	Best Case	Most Likely	Worst Case
Sales			
Room Rentals	(+5%)	100%	(-5%)
Other Revenue	(+5%)	100%	(-5%)
Cost			
Operating Cost	(-5%)	100%	(+10%)
Marketing Cost	(-5%)	100%	(+10%)
NPV	$6,589,122	$3,434,298	-$672,680
IRR	20%	16%	11%
Pay Back	7.98	8.98	10.90

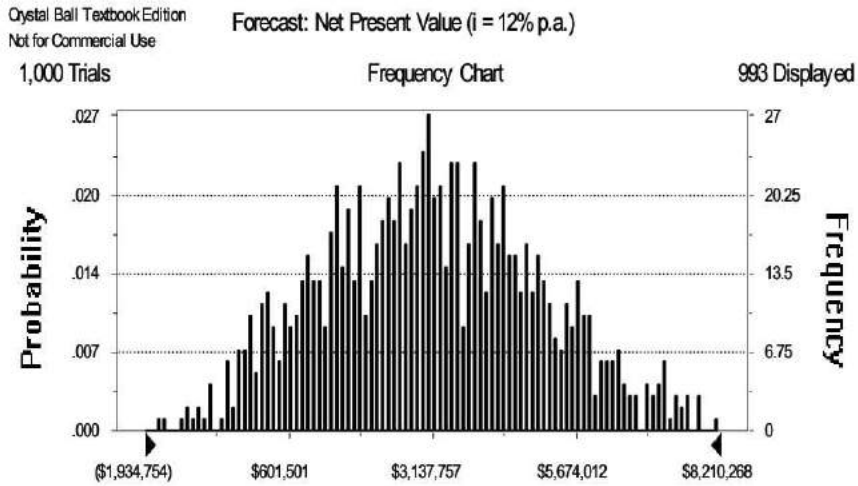

Figure 3: Probability distribution of Net Present Value

4.4 Phase #4 - Risk/Return Tradeoff

The qualitative risk model developed in this final phase to provide analysts with a logical framework to arrive at an investment decision is shown in Figure 4. First a weighted average cost of capital (WACC) is calculated using a financing structure used on comparable projects. In this case, the WACC was computed at 7.45%. Then the risk factor hierarchy shown in Figure 4 was used to facilitate the rapid identification of the high risk areas associated with the proposed venture. These risks were related to location, market, technology, financial, and investment factors. The DHCC business venture was deemed to be a high risk project thus requiring a minimum acceptable rate of return (MARR) of 12.67% as shown

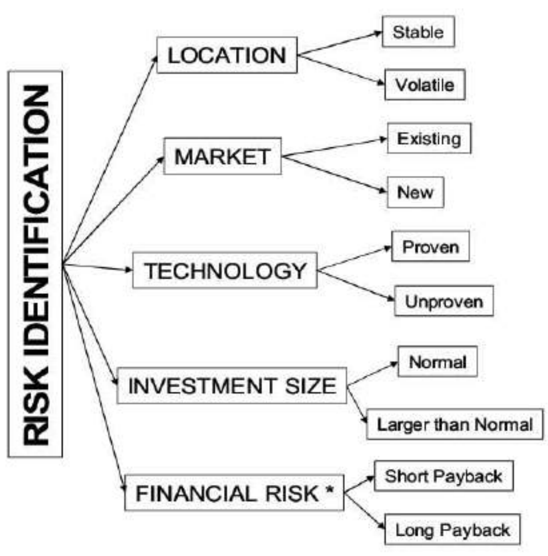

Figure 4. Risk factors in new global ventures

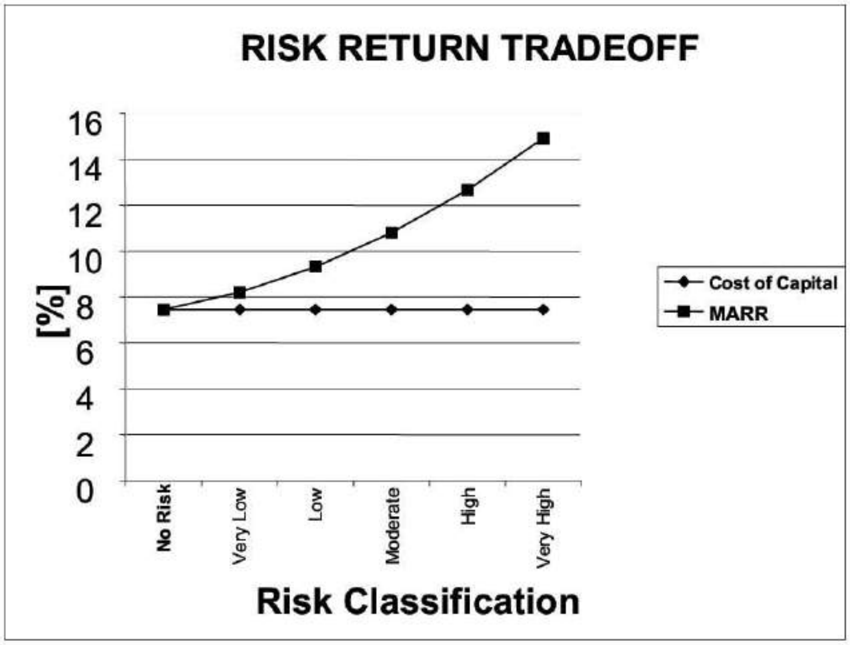

Figure 5. Risk/return tradeoff in new global venture

in the risk/return tradeoff diagram in Figure 5. In Phase #2 – Financial Evaluation, the new venture reported an internal rate of return of 16%. Since this exceeds the minimum acceptable rate of return, this new global venture was regarded as being marginally acceptable and worthy of the investment of additional resources in conducting a more detailed pre-feasibility study.

1. Discussion and conclusion

Our structured approach to Risk Management was obtained by the synergistic integration of the well-proven project evaluation methodology adopted by UNIDO with Boehm's spiral model for software development to provide a robust, replicable framework for assessing risk on new, global ventures. In the case study discussed, a qualitative risk model was deployed to complement the more traditional risk management techniques by capturing the risks associated with the first phase of the business development process and facilitating an investment decision on the project. In this case, the analysis suggested that the venture had successfully cleared the first hurdle of the *Opportunity Study* and should now be subjected to more in-depth analysis during a pre-feasibility study with the aim of moving towards a detailed feasibility study once a specific site was selected and design specifications established for the venture. Further work will entail applying the framework through all phases of a venture and expanding its use to evaluate global business ventures in other sectors such as manufacturing, healthcare, information technology and consumer products. However, our experience in this case study from the tourism sector suggests that the framework can provide a robust, replicable methodology to conduct the risk/return tradeoff often required in managing risks in new global business ventures.

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Development of a Low-Cost Weigh-in-Motion System

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Abstract

Limiting the weight of vehicles that use a given roadway is essential to prolonging the life of the roadway pavement and can also impact safety. Enforcement of weight limitations requires some method of weighing the vehicles that are using the roadway; however, the scales that are commonly used for this purpose are costly to install. This paper reports on investigations into a low-cost weigh-in-motion (WIM) system using acoustic emission technology. Laboratory testing of the concept was conducted and verified that a correlation exists between various acoustic emission parameters and applied load (vehicle weight). Field-testing of the proposed equipment has begun and initial results are presented.

1. Introduction

In an effort to extend the useful life of roadway pavement and improve vehicle safety, weight limits have been set for heavy trucks utilizing the nation's highways. [1] To enforce the weight limits, trucks are weighed at weigh stations along the highway and overweight vehicles are ticketed and/or fined. Weigh stations take a variety of forms, including:

- traditional weigh stations where heavy vehicles are pulled off of the highway and weighed on low-speed WIM scales and/or stationary scales, and
- Remotely Operated Compliance Stations (ROCS™) where heavy vehicles are weighed at highway speeds in the travel lanes. [2-6]

Typical weigh stations collect information about axle weight, axle configuration and spacing, and whole vehicle weight. In addition to weight enforcement, this data can also be used for a variety of transportation planning purposes, including the design of pavement and bridge structures, planning transportation facilities, and safety analysis. [7]

Static scales measure the weight of a vehicle at rest. Because of the large size of the vehicles involved, the scales are usually built to weigh only one axle at a time. That is, the vehicle is parked with just the front axles on the scale and the weight is measured, then the vehicle is moved so that the second set of axles rests on the scale, and so forth. Accurate measurement relies upon level pavement around the scale and upon the elimination of other sources of error such as load shifting between measurements. [8]

WIM systems, on the other hand, measure the dynamic forces associated with a vehicle in motion passing over the scale. The accuracy of a WIM system is affected by the type of suspension system present in the vehicle being weighed, the type of pavement (flexible or rigid), and the profile of the pavement surrounding the scale. [9]

Several different technologies are currently in use in WIM systems. The bending plate WIM system consists of steel plates surrounded by rubber and connected to strain gauges. The vehicle weight is related to the strain on the plates as the vehicle crosses over them. [10] Similarly, a WIM system can be created by measuring strain in a structure (a bridge, for instance). [11]

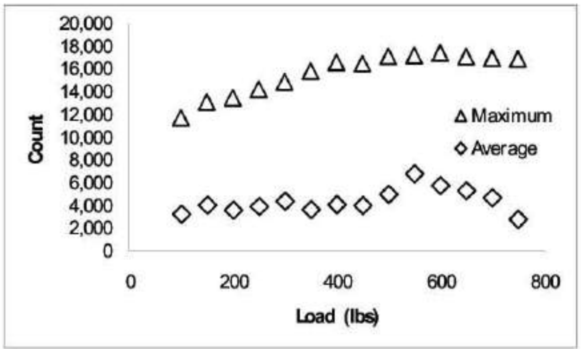


Figure 3. Count as a function of weight

Similar trends are found when energy and absolute energy are considered. Figure 4 shows a distinct trend of increased energy with increased load when the maximum hit for each TB is isolated. Figure 5 shows similar results for absolute energy.

No correlation was found between the parameters risetime, counts to peak, duration, or amplitude and load.

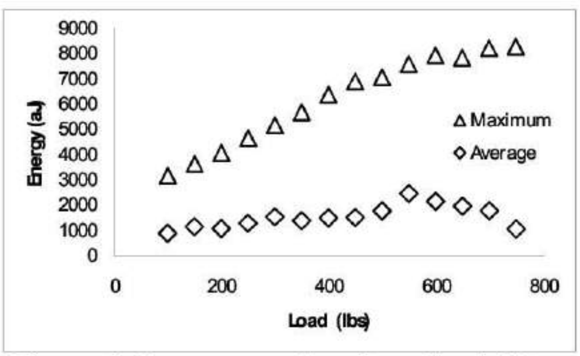


Figure 4. Energy as a function of weight

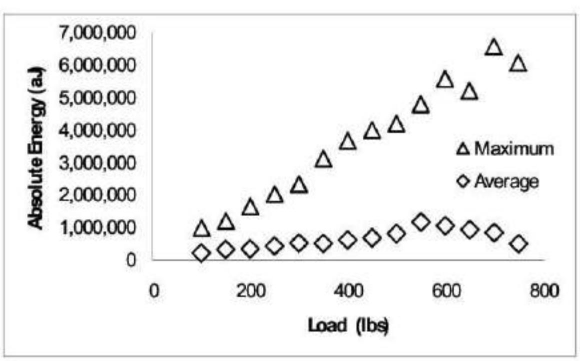


Figure 5. Absolute energy as a function of weight

7. Laboratory test results, experiment two

The second experiment focused on energy, count, and absolute energy because they were shown to be most highly correlated with load. Because the results for count, energy, and absolute energy are similar, this paper focuses on the results only in terms of energy.

An analysis was done comparing the maximum energy hit from each TB for each of the twelve settings. Energy was found to increase with load and with proximity to the sensor. Unfortunately, the variability in the data is too large to allow identification of the load based solely on the maximum energy hit in a TB. Figure 6 shows the average and standard deviation of maximum energy values for the 30 TBs at each of the 12 settings. Data points that were more than two standard deviations from the norm were deemed outliers and were not used in the calculation of average and standard deviation shown in the figure.

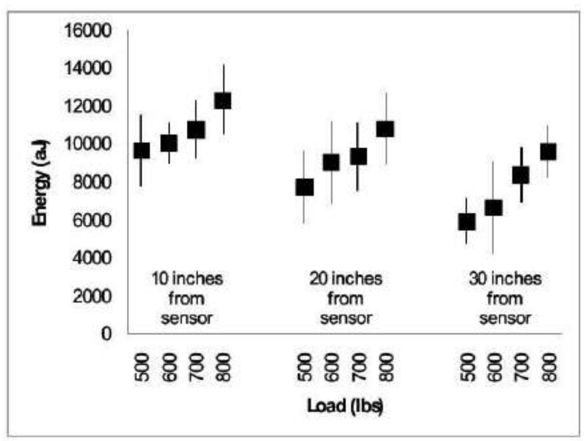


Figure 6. Maximum energy per TB

8. Field test methodology

Field (road) tests were conducted at the University of Central Florida campus. The metal strip used for this testing is long enough to extend completely across a 12 ft (3.7 m) lane, with room on either end to attach the acoustic sensors. For the first field test (experiment three), the metal strip was attached to the pavement using duct tape, with connection points every 6 inches (15 cm). Only one acoustic sensor was used. The test vehicle was a Sierra GMC truck, with a curb weight of approximately 4,000 lbs (1800 kg). The test vehicle was driven at 10 mph (16 km/h) and at 20 mph (32 km/h), under two weight conditions: empty (except for the driver) and with an additional weight of approximately 700 lbs (320 kg). Figure 7 shows the test vehicle, the computer set-up, and the metal strip taped to the roadway.

Because the road surface wasn't planar, the metal strip did not adhere firmly to the road surface and bouncing of the metal strip was observed. Since this bouncing appeared to affect the results, for the second field test (experiment four) the metal strip was firmly attached to the pavement using an epoxy glue along the length of the strip. Two acoustic sensors were used, one on each end of the test strip. The same test vehicle and speeds were used, but this time there were three weight conditions: empty, an additional weight of approximately 500 lbs (225 kg), and an additional weight of approximately 1000 lbs (450 kg). One test run was made at 30 mph (48 km/h) to determine if it was feasible to run trials at this speed; however, there was not enough distance to safely reach a speed of 30 mph and then slow down afterwards, so subsequent runs at this speed were not made.

9. Field test results

Whereas in the laboratory the relative variation in the load was large (100 lbs to 750 lbs) and the relative variation in the speed was small (2 mph to 4 mph), the opposite was true of the field tests. In the field, the relative variation of load was small (4,000 to 5,000 lbs) and the relative variation in speed was high (10 mph to 30 mph).

Consequently, in the field, correlations were found between the acoustic emission parameters and speed, but no correlations were found between any of the acoustic emission parameters and weight.

The vehicle that was used in the testing has two axles, each of which has two tires that strike the metal strip at approximately the same time. Therefore, for the field testing each strike of the metal strip is referred to as an axle bump (AB). During one repetition of the experiment, two ABs are collected, referred to as AB 1 (front axle) and AB 2 (rear axle). Figure 8 shows the typical pattern of hits collected during one repetition of the experiment. Note that the vibrations from the vehicle striking the metal strip remain for some period after the vehicle has completely passed. The time from when the vehicle first strikes the metal strip until these vibrations have died away is known as the acoustic emission duration.

Figure 7. Photo showing set up for the field testing in May 2007

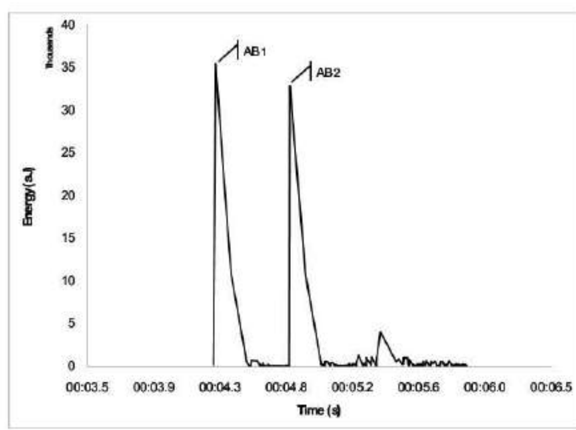


Figure 8. Typical pattern of energy in hits during one repetition (2 ABs)

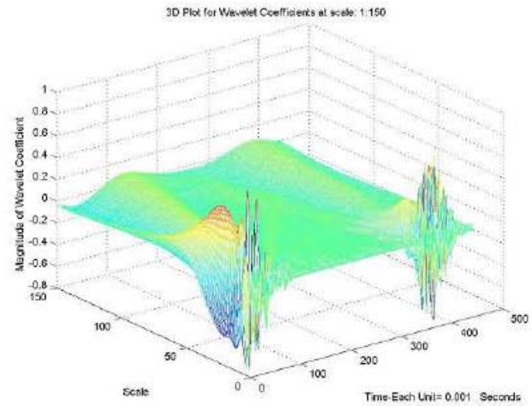


Figure 9. 3-D plot of wavelet coefficients

The speed of the truck can be computed from the time between the ABs and a knowledge of the distance between the axles [116 inches (295 cm)]. The results for different speeds are summarized in Table 1.

Table 1. Pick-up Truck Test Results

Speedometer reading (mph)	Computed speed (mph)
5	4.2
10	12.4
20	19.4
25	24.4

In addition to the acoustic emission parameters described above, the wavelet coefficient can also be determined. Figure 9 shows a 3-D plot of the wavelet coefficients. Plotting the maximum value of the wavelet coefficient for different truck speeds yields Figure 10, which clearly demonstrates the correlation between the speed of the truck (same weight) and the computed maximum wavelet coefficient.

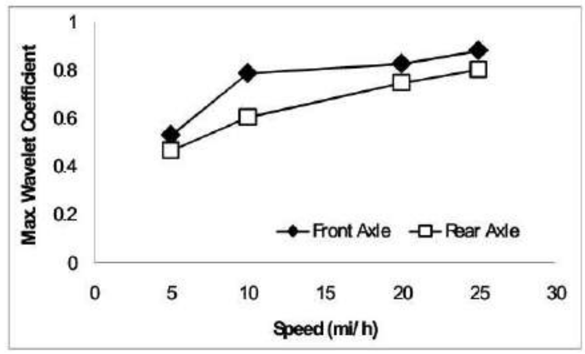
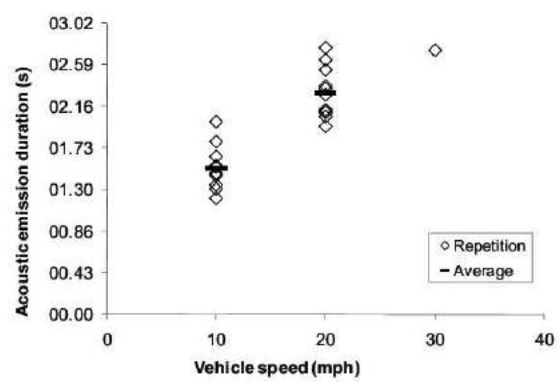


Figure 10. Correlation between maximum wavelet coefficient and truck speed

A correlation can also be made between the acoustic emission duration of each run and the speed of the vehicle. Figure 11 shows the values of these variables for each run and the averages for 10 mph (16 km/h) and for 20 mph (32 km/h).

Figure 11. Acoustic emission duration as a function of truck speed



11. Acknowledgements

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Implementation of the Design Structure Matrix Method in Engineering Development Projects

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Abstract

Traditional project management tools such as Program Evaluation and Review Technique (PERT), Critical Path Method (CPM), and Gantt chart allow the modelling of sequential and parallel processes in projects, but they fail to address interdependency of feedback and iteration, which is common in complex engineering development projects. One method of explicitly accounting for iteration in the design process, Design Structure Matrix (DSM), is presented. In this paper, ways of improving planning, execution and management of projects using the DSM algorithms (partitioning and tearing) are presented. The model is tested on a set of tasks in a complex petroleum oil field development project. By applying the DSM method, the project duration is optimized and hence the total cost of the petroleum oil field development project is reduced significantly.
Keywords-Design Structure Matrix, Partitioning, Project Management, Scheduling, Tearing.

1. Introduction

A challenging aspect of managing the development of complex projects is the notion of design iteration, or rework. Since potential savings could be optimized by minimizing the amount of rework in the design process, it is desirable to have management methodologies that consider rework. Traditional project management tools such as PERT (Program Evaluation and Review Technique), CPM (Critical Path Method) and Gantt chart tools allow the modelling of sequential and parallel processes in projects, but they fail to address interdependency a feedback and iteration, which is common in a complex engineering development project and a design process [1-4].

In this paper, a method to account for feedback and iteration, a matrix based tool called the Design Structure Matrix (DSM) is presented. The Design Structure Matrix (DSM) also known as the Dependency Structure Matrix, the Problem Solving Matrix (PSM) and the Design Precedence matrix is a project management tool used for representing and analysing dependencies [5-8]. The DSM was developed by Warfield (in the 70's) and Steward (1981). The method received attention by Massachusetts Institute of Technology (MIT) research in the design process in 1990.

2. DSM Layout

The DSM is a compressed, matrix representation of a project. The matrix contains a list of all tasks. It shows what information is required to start a certain task and where that information from that task feed into, which other tasks in the matrix use the output information [6]. In the DSM model, a project task is assigned to a row and a corresponding column. The rows and columns are named and ordered identically. Each task is defined by a row of the matrix. We represent a task's dependencies by placing marks ("x", "o" or "1") in the columns to indicate the other tasks (columns) on which it depends. Reading across a row reveals all the input tasks and reading down a column reveals the output tasks as shown in Figure 1.

The diagonal tasks of the matrix do not have any interpretation in describing the system, they are either left empty, blacked out, filled in with the task labels or task duration. This is done to separate the upper and lower triangles of the matrix and to show more clearly the tracing dependencies.

	A	B	C	D	E	F
A						X
B	X				X	
C						
D		X				
E			X			
F						

Figure 1. A DSM representation of a project

The marks below the diagonal indicate *forward flow* of information. For example, task B needs information from task A. The marks above the diagonal indicate a *feedback* from a later (downstream) task to an earlier (upstream) one. For example, task A needs information from task F.

2. Partitioning the DSM

The DSM can be used to improve the planning, execution and management of complex projects using different algorithms, which are partitioning, clustering, tearing, banding, simulation and eigenvalue analysis. Partitioning [9-12] is the process of rearranging the order of activities in such a way so that the dependency relationships are brought either close to the diagonal as possible (this form of the matrix is known as block triangular) or below the diagonal, changing the DSM into a lower triangular form. Fewer elements in the system will be involved in the iteration cycle. The outcome is a faster development process. There are many approaches used in DSM partitioning, they are similar but different in how they identify cycles (circuits or loops) of information.

The algorithm for the formation of a partitioned DSM is explained below:

i) Consider an activity DSM.
ii) Observe for any marks along the upper diagonal (feedback/loop/circuits) of the matrix. If there are no marks along the upper diagonal it means that the matrix is partitioned. Stop the procedure or continue with the next step.
iii) Check for empty rows (activities that do not have input from the rest of the activities in the matrix) and move all the empty rows to the top of the matrix and the corresponding columns to the left of the matrix and leave out these activities from further consideration. Empty rows represent the start activities. The remaining activities in the matrix form the active matrix.
iv) From the active matrix, check for any empty columns (deliver no information to other activities in the matrix) and move all these empty columns to the right and the corresponding rows to the bottom of the active matrix and leave out these activities from further consideration. Empty columns represent the finish activities.
v) Repeat steps iii and iv until there are no empty rows and columns in the active matrix. Repeating the above process allows to identify the dependent activities. Steps i-v are known as the Topological Sorting Algorithm.
vi) Determine circuits/loops by a Path Searching method.
vii) Merge/condense all the activities in the loop to form a block.
viii) Repeat the final condensed matrix to find the block sequence.

In the Path Searching method, information flow is traced forwards or backwards until a task is come across twice [9]. To trace out the circuits/loops choose a mark in a row, then read up to the column value. Go to the same row value of this column and read up to the column. Continue reading across the rows until that same mark, read from the first column appears again. All the tasks between the first and second occurrence of the task form a loop of information flow. When all loops in the DSM have been identified, and all tasks have been scheduled, the sequencing is complete and the matrix is in block triangular form.

3. Tearing the DSM

Tearing also known as decoupling is used to decompose blocks in a DSM [9]. It is the process of selecting the set of feedback marks that if removed from the matrix, (and the matrix is re-partitioned) turning the matrix into the lower triangular. The marks that are removed from the matrix are called "tears". Identifying "tears" that result in a lower triangular matrix means that we have identified the set of assumptions that need to be made in order to start the design process iterations when coupled tasks are come across in the process. Having made these assumptions no additional estimates need to be made. To achieve savings in the process without a considerable loss of system accuracy tearing assists in deciding if certain couplings could be removed (or temporarily suspended) from consideration by using coupling strengths to tear the analyses (using sensitivity information).

There is no best method for tearing, it is recommended to use these two criteria when making tearing decisions:

i) Minimal number of tears: This is because tears represent an approximation or an initial guess to be used; we would rather reduce the number of these guesses used.
ii) Restrict tears to the smallest blocks along the diagonal: This is because if there are to be iterations within iterations (i.e. blocks within blocks), these inner iterations are done more often. Therefore, it is desirable to restrict the inner iterations to a small number of tasks.

4. Case Study - Petroleum Oil Field Development Project

The objective of the Petroleum Oil Field Development (POFD) project is to design a development plan for a new oil field discovered after drilling a number of wells. The development plan consists of oil producers, water/gas injectors and surface facility to handle the produced oil, water and gas. In this project, DSM operations will be implemented to improve planning, execution and managing the project by reducing the number of feedbacks and reducing the project duration using partitioning and tearing algorithms.

This project is divided into five areas: Conduct Reservoir Rock Type (RRT) Study, Build Static Model, Conduct Special Core Analysis (SCAL) Study, Build Dynamic Model, and Conduct Pressure Volume Temperature (PVT) Study. The project is an activity based performed involving: Team leader/manager, Reservoir Engineers, Petroleum Engineers, Geologists, and Petrophysists. Project duration is estimated about 100 days and this project involves 24 tasks as follows:

1.1 Review & Prepare Data
1.2 Collect Samples
1.3 Define Reservoir Rock Types (RRT)
1.4 Prepare Data for Static Model
2.1 Input Data
2.2 Build Reservoir Framework
2.3 Build 3D Property Model (s)
2.4 Manipulate & Rank Models
2.5 Build 3D Flow Simulation Grid (s)
3.1 Study Existing Data Sources
3.2 Conduct Coring
3.3 Conduct Rock Characterization
3.4 Conduct Geo-mechanical Studies
3.5 Conduct Special Core Analysis (dynamic displacement experiments)
3.6 Do Routine & Special Core Interpretation
4.1 Input Data
4.2 Initialize Reservoir Dynamic Model
4.3 Do History Matching
4.4 Do Development Predictions
5.1 Study Existing Data Sources
5.2 Collect Samples
5.3 Conduct Standard PVT Study
5.4 Conduct Specialized PVT Study
5.5 Develop PVT Applications

In the next sections, all these tasks will be put into the DSM structure. Then, the partitioning and tearing operations will be implemented to optimize the scheduling of this project.

5. Constructing the Petroleum Oil Field Development Project in DSM

We interviewed a reservoir engineer specialist to determine the inputs and outputs for the list of tasks and the task durations (days) involved in the project. We input the marks and the task durations (along the diagonal) into the matrix as shown in Appendix 1.

The aim of partitioning the DSM is to maximize the availability of information required, and minimize the amount of iterative loops within the process. The process is ordered to minimize the number of dependencies above the diagonal. Partitioning the matrix sequences the tasks that do not contribute to iterative loops and indicates the tasks that are within iterative loops, but does not sequence the tasks within the loops. This is because the tasks that contribute to a loop are all inter-related, and any of them can be the first task carried out in the completion of the loop. It is desirable that the tasks within a loop are ordered to reduce the number of estimates and iteration within the process. The first step of the process is the topological sorting before we identify loops/circuits using path searching procedure which is presented later.

5.1 Topological Sorting

Tasks 1.2, 3.1, 3.2, 5.1 and 5.2 do not depend on any information from any other tasks, as shown with an empty row. We will schedule these tasks fist and leave out from further consideration. Tasks 3.4 and 3.5 depend only on task 3.2; we will schedule these tasks after task 5.2. Tasks 5.3 and 5.4 depend only on task 5.2. We will schedule these tasks after tasks 3.4 and 3.5. Task 5.5 depends on only tasks 5.1, 5.3 and 5.4. We will schedule task 5.5 after task 5.4 and leave out this task from further consideration. Task 4.4 does not deliver information to any other tasks in the matrix, as shown by an empty column. We will move task 4.4 to the right and corresponding row to the bottom of the matrix and leave out this task from further consideration.

5.2 Identifying Loops/Circuits using Path Searching Procedure

We trace forward starting with the remaining tasks that contain marks above the diagonal. We read across row 1.1, identify a mark and read up to column 3.6. We read across row 3.6, identify a mark and read up to column 3.3 (we ignore the other marks across the row of 3.6 because we have already scheduled those tasks using topological sorting). We read across row 3.3, identify a mark and read up to column 1.3. We read across row 1.3, identify a mark and read up to column 1.1. From this information tasks 1.1, 1.3, 3.3 and 3.6 are involved in a circuit. We will schedule these tasks after scheduling the first tasks in topological sorting and leave out these tasks from further consideration. These tasks will form a block in the matrix.

We trace forward task 2.5 (because it contains a mark above the diagonal) we read across row 2.5, identify that mark above the diagonal and read up to column 4.3. We read across row 4.3, identify a mark and read up to column 4.2. We read across row 4.2, identify a mark and read up to column 4.1. We read across row 4.1, identify a mark and read up to column 2.5. From this information tasks 2.5, 4.1, 4.2 and 4.3 are involved in a circuit. These tasks will form another block in the matrix.

5.3 Tearing the Blocks

From partitioning the DSM we have identified two blocks. We will select the set of feedback marks that if removed from the matrix, (and the matrix is re-partitioned) turning the DSM into the lower triangular. The aim of tearing is to break the information cycle in each block (i.e. task subsets involved in a cycle) and establish a possible starting executions sequence for this subset of tasks.

5.3.1 Block 1

It consists of tasks 1.1, 1.3, 3.3 and 3.6. Any one of these tasks will result in breaking the circuit. We will make an assumption and tear dependency link of task 1.3.

5.3.2 Block 2

It consists of tasks 2.5, 4.1, 4.2 and 4.3. Any one of these tasks will result in breaking the circuit. We will make an assumption and tear dependency link of task 4.1.

We will re-partition the matrix where the torn tasks are scheduled first within block 1 and 2. Because there are marks still above the diagonal after tearing the feedback marks, task 1.3 in block 1 and task 4.1 in block 2, we must re-partition (i.e. reorder the tasks) within the blocks.

5.3.3 Re-partitioning Block 1

We ignore the torn row marks in task 1.3. Task 1.1 is scheduled last within the block because it does not deliver information to other tasks, as shown by an empty column (ignoring the torn row mark from task 1.3) in the block. This results in eliminating the feedback mark from task 1.1. There is no need to reorder any other tasks within block 1 since the tasks (except task 1.3 was torn) are below the diagonal in the lower triangular form as shown in Appendix 2.

5.3.4 Re-partitioning Block 2

We ignore the torn row marks in task 4.1. Task 2.5 is scheduled last within the block because it does not deliver information to other tasks, as shown by an empty column (ignoring the torn row mark from task 4.1) in the block. This results in eliminating the feedback mark from task 2.5. There is no need to reorder any other tasks within block 2 since the tasks (except task 2.5 was torn) are below the diagonal in the lower triangular form as shown in Appendix 2.

The removal of feedback link of task 1.3 and 4.1 results in breaking the circuit within the blocks. There are no other circuits in the matrix indicated by the no "X" marks (except task 1.3 and 4.1 was torn) above the diagonal, hence turning the DSM into the lower triangular form.

5.4 Constructing the Petroleum Oil Field Development Project in CPM Chart

Since there are no marks above the diagonal, hence turning the DSM into the lower triangular form, we can apply traditional project management tools such as PERT/CPM. From the critical path of the CPM chart shown in Appendix 3, it is noticed that the project duration is now 86 days. The original duration was 100 days; therefore we have saved 14 working days, hence reducing the total cost of the development plan for a new oil field discovered after drilling a number of wells.

6. Conclusions

The DSM is a new approach to project management, used to represent, analyze dependencies among tasks and show the order in which tasks are preformed. This method provides a way of managing feedbacks in complex product development and engineering design projects. The DSM is an alternative approach to traditional project management tools. The main advantage of the DSM over traditional project management tools is in its compactness and ability to present an organized and efficient mapping among tasks that is clear and easy to read regardless of size.

In partitioning the DSM, we used a path searching method to identify loops/circuits. Partitioning the DSM resulted in minimizing the amount of iterative loops by half, therefore reducing the amount of delay in the project. We initially had 4 feedbacks, partitioning resulted in 2 feedbacks, hence we reduced the number of dependencies. Analyzing the partitioned DSM revealed which tasks were parallel, which were sequential and which were coupled. The outcome from partitioning the DSM was a faster development process by optimizing the availability of information in the Petroleum Oil Field Development project.

Tearing the DSM resulted in breaking the information cycle in block 1 and 2 in the project, but both these methods are based on assumptions hence the torn dependency link could be vital to the completion of the project and can cause a risk of iteration among other tasks.

Since we reduced all the feedback marks in the DSM, we applied a traditional project management tool and constructed a CPM chart after interviewing engineers about the appropriate task durations. The original project duration was 100 days, by applying partitioning and tearing algorithms we reduced the project duration to 86 days, therefore saving 14 working days, hence reducing the total cost of the development plan for a new oil field discovered after drilling a number of wells.

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Table 1. DSM Representation of the Petroleum Oil Field Development Project

	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2	4.3	4.4	5.1	5.2	5.3	5.4	5.5
1.1	5														X									
1.2		15																						
1.3	X	X	5																					
1.4			X	10																				
2.1				X	5										X									
2.2					X	5																		
2.3				X		X	5																	
2.4							X	2																
2.5								X	10									X						
3.1										15														
3.2											5													
3.3			X								X	10												
3.4											X		10											
3.5											X			10										
3.6										X		X	X	X	10									
4.1									X						X	5								X
4.2																X	3							
4.3																	X	5						
4.4																		X	15					
5.1																				10				
5.2																					5			
5.3																					X	15		
5.4																					X		30	
5.5																				X		X	X	10

Table 2. Final DSM Representation After Partitioning and Tearing Algorithms Performed

	1.2	3.1	3.2	5.1	5.2	3.4	3.5	5.3	5.4	5.5	1.3	3.3	3.6	1.1	1.4	2.1	2.2	2.3	2.4	4.1	4.2	4.3	2.5	4.4
1.2																								
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1.3	X													X										
3.3			X								X													
3.6		X				X	X					X												
1.1													X											
1.4											X													
2.1													X		X									
2.2																X								
2.3															X		X							
2.4																		X						
4.1										X			X										X	
4.2																				X				
4.3																					X			
2.5																						X		
4.4																						X		

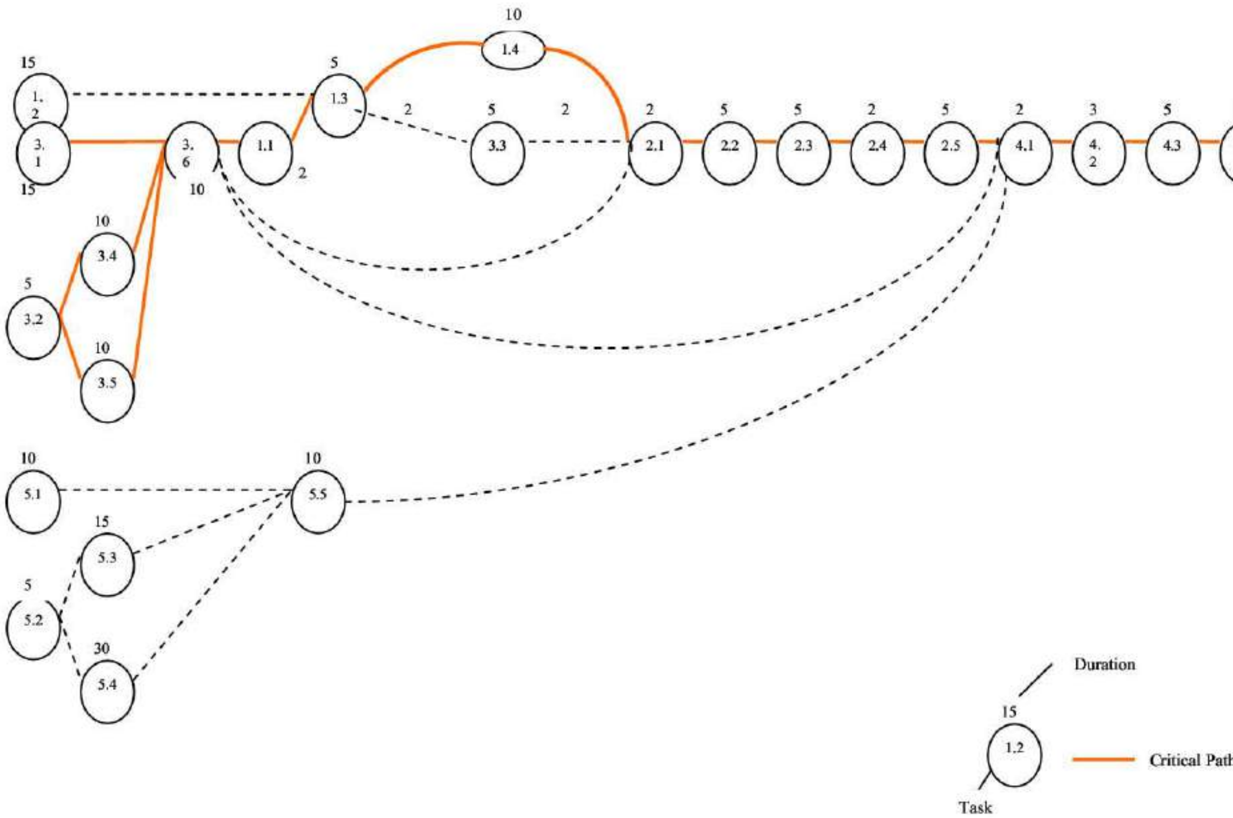

Figure 2. CPM chart of the Petroleum Oil Field Development Project

Moving From Captive Offshoring to Offshore Outsourcing

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Abstract

During the last decade many firms made the move offshore via captive offshoring. Today, we are witnessing a move away from captive offshoring and towards offshore outsourcing. This paper discusses the relative merits of both types of outsourcing models and then identifies and discusses the current trend towards offshore outsourcing.

1. Introduction

During the last decade many firms made the move offshore using a captive offshoring model. These models worked well because they allowed firms to achieve cost advantages, gain access to resources not available domestically, and opened up valuable foreign markets. These models also allowed them to retain control of their processes and businesses in host countries that were still developing.

Today, we are witnessing a move away from captive offshoring and towards offshore outsourcing. The primary reason for this move is that many of these host countries and potential foreign suppliers have developed sufficiently to lessen the risks inherent in offshore outsourcing.

Why is this trend occurring? What, if anything, has happened in these host country environments that has seemingly made it more enticing for companies to switch to an offshore outsourcing strategy? In this paper we address these questions by first examining some of the characteristics, benefits, and risks of captive offshoring and those of offshore outsourcing. We then discuss the motivation for this developing trend, and why it's important.

2. Captive offshoring

Captive outsourcing can be defined as [6, p. 716] "any offshore arrangement where a firm maintains ownership of the function and related technology of an operation." For purposes of this paper, we consider that the captive firm is a wholly owned business organization. Most often a firm's primary goal is something other than simply cost reduction, although that may play a role.

Captive offshoring takes a significant amount of organizational effort and requires large capital expenditures [5]. For firms that are looking to service new foreign markets while taking advantage of lower material, labor, and/or transportation costs, captive offshoring is viewed as an important vehicle.

Firms with experience in captive offshoring that pursue multiple locations can optimize their operations provided that the prevailing environmental conditions in the host country locations are favorable. Some of the benefits and risks of captive offshoring are shown below [6].

Benefits of captive offshoring include:

- cost reduction from labor, material, operating environment, etc.,
- access to skills or competencies while maintaining control of technology and intellectual property,
- gaining the ability to choose the markets and entry strategies while maintaining control of the firm's image,

- maintaining existing vertical integration but at a more strategic location,
- gaining access to where the resources are most economically utilized, and
- gaining greater coordination of multiple locations.

Risks of captive offshoring include:

- being hit with hidden costs and experience curve delay that may hurt ROI,
- impeding the realization of benefits because of cultural barriers,.
- endangering profit margins and ROI with regulatory hurdles and competition,
- being vulnerable to supplier interruption,
- experiencing detrimental change to the long-run outlook of the firm because of changes in the political situation of the host country, and
- experiencing reduced flexibility if conditions deteriorate due to the "stickiness" of individual locations

According to a report by Morgan Chambers, plc [11], companies should opt for captive outsourcing when the following conditions are present:

- there are serious problems with long-term offshore contracts,
- the company needs to exercise complete control over the operation,
- security in the host country is an issue,
- the organization requires high-level skills or IP protection and there is a concern regarding high levels of attrition,
- the organization seeks cost and labor arbitrage,
- captive offshoring can be used to support market entry, and
- the organization follows a build-operate-transfer (BOT) strategy.

3. Offshore outsourcing

Offshore outsourcing can be defined as [6, p. 715] "any arrangement with an offshore firm in which the work activities are transferred away from a company's own operations." These arrangements refer to the use of suppliers and/or service providers. Typically firms have pursued offshore outsourcing to take advantage of another firm's capabilities while focusing on their own core competencies. Achieving greater flexibility in operations, accessing new technology and/or other resources, and pursuing unfamiliar markets without making the investment required with captive offshoring are among the reasons firms choose offshore outsourcing [6].

With larger volumes of business, suppliers have often achieved significant economies of scale and have built a strong base of skills. The resulting cost to outsource is often considerably less than performing the same task in-house, and the quality of the outcome is often far better than what can be achieved in-house. Therefore, firms gain the advantages inherent in the areas of competency and skills without having to make a significant capital outlay. Thus the organization achieves flexibility in aligning resources and market objectives almost immediately. Some of the benefits and risks of offshore outsourcing are listed below [6].

Benefits of offshore outsourcing include:

- lower costs which can be achieved from labor, material, operating environment, etc., as well as the supplier being further down the learning curve,
- gaining a well established base of skill of competency from the supplier,
- utilizing the supplier's knowledge of local market conditions, infrastructure and additional needs,
- working with a supplier that has established relationships with key second-tier suppliers,
- acquiring a more flexible arrangement to procure needed resources, and
- allowing the firm to "operate" offshore without making extensive capital investments.

Risks of offshore outsourcing include:

- absorbing hidden costs, supplier margins, and potential negative press,
- exposure to rising costs as demand for skills intensifies,
- exposure to an operating environment that may not suitably protect the relationship or intellectual property,
- becoming vulnerable to supplier interruption, and
- receiving unreliable or reduced service levels.

Hebb and Janaro [6] looked at situations involving forms of offshoring for SMEs. They concluded that offshore outsourcing is more appropriate than captive offshoring whenever:

- the process is standard and the outsourcing partner is capable of meeting the product's specifications,
- a small number of non-core products is involved,
- outsourcing will free up resources which can be used for producing higher priority products, and
- the outsourcing partner can provide specialized skills and/or new technologies that are difficult or expensive to acquire.

These appear to be consistent with conventional wisdom for any size firm.

4. Captive offshoring versus offshore outsourcing: the current trend

In the early days of pursuing foreign operations, captive offshoring was popular due to the large number of initial success stories. Additionally, host country suppliers had little experience while so-called global 3PLs were still developing their offshore capabilities [2]. Of course the most alluring reason to favor ownership rather than outsourcing was that ownership provided the strategic value and ability to coordinate and control operations.

In manufacturing, companies looked to Japan in the '60s and '70s. In the '80s Mexico became a hotspot. More recently, China has become a Mecca. In the areas of IT, services, and R&D, India has been the country of choice. In each of these venues, U.S. and U.K. based businesses made sizable investments in organizing and developing captive firms, trained their new workforces, and encouraged host countries to improve their infrastructures. In exchange they received some combination of cost savings, labor skills, technical expertise, and market access, among other benefits. Most importantly, they did it *their way*; they kept control over operations and their core competencies. These companies represent the success stories of captive offshoring.

Other companies have not fared as well in that they have not been able to reach their potential. Several reasons have been cited for these less than favorable results [2, p. 6]:

- "It often takes longer than expected to reach operational stability. Companies put an initial stake in the ground, but often lose momentum before reaching the scale necessary to substantially reduce costs.
- A shortage of experienced people in immature outsourcing markets makes it difficult to recruit, train and retrain skilled staff and managers. Cultural and language issues pose a constant challenge.
- Customers are not prepared for change. Companies often run into trouble when they move customer service for their largest, best clients to emerging offshore centers."

Bierce, et al [2], report that there currently exists a trend away from captive offshoring. They report that a number of companies are divesting themselves of their captive firms and engaging in offshore outsourcing and cite several reasons for this shift, including:

- many suppliers now have the scale, assets, and capabilities to perform a variety of tasks in these foreign markets, and

- in more developed foreign markets price pressures and keen competition for the best talent have emerged.

Moreover, the nature of the work being outsourced is also changing.

According to a number of sources (e.g. [1] and [3]), the types of outsourced activities are continuing to move up the value chain to include more knowledge type work performed by professionals. Such work has traditionally been considered among the core activities of the business. These include work in clinical trials management, reading and interpreting x-rays and MRIs, and designing computer chips, among others. In a study of Japanese manufacturing industries using data from 1994 to 2002, Jiang, et al [7] found that core business-related offshore outsourcing had positive effects on the outsourcing firms' market value while non-core business outsourcing did not enhance the market value of the outsourcing firms. This represents a departure from conventional wisdom which says do not outsource core activities, only activities that do not have a strategic effect on the business.

Another interesting finding by Couto, et al [4] was that for the most part offshoring of higher-level core work has not resulted in the loss of jobs in the home country. Instead, such offshoring has been aimed at seeking new sources of high-skilled talent when that talent has not been available in the home country. This makes sense when looking at engineering enrollments for bachelors degrees in U.S. schools (See Figure 1 [10]). Since 1991, enrollments have been relatively flat, while demand has been growing, creating a shortage of engineering talent. Therefore, companies have gone offshore to acquire those skills.

As good as this sounds, it does come with some built-in problems. Since offshore vendors will become more like an extended part of the organization, this will lead to the emergence of governance becoming a key issue [1]. It's not surprising then that managing the outsourcing relationship was found to be the most underestimated issue in offshore outsourcing. Couto, et al [4] and Sanders, et al [9] found that this was the case even when contracts were clear and preset service levels were in place.

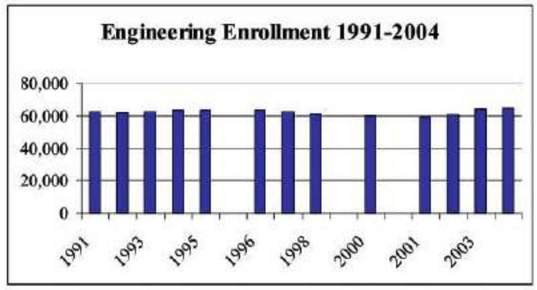

Figure 1. Engineering Enrollment From 1991 to 2004

In a study involving senior executives experienced in outsourcing and representing both service and manufacturing industries, Sanders et al [9] found that the primary cause of failure of a satisfactory outcome in offshore outsourcing was the firm's inability to manage effectively the client-supplier relationship. Adding further to the difficulty of managing relationships, Clott [3] found that project managers who were charged with implementing complex offshore arrangements received relatively little scanning information from senior management. This left them faced with cultural and communications issues, among others, that they were not adequately prepared to deal with.

Two important questions now emerge:

- If the trend for the form of offshoring is moving away from captive and towards outsourcing, then is captive offshoring ever a reasonable choice?
- If a company is currently engaged in captive offshoring, then is there a "right time" for divesting and then pursuing offshore outsourcing?

In response to the first question, at least two strong arguments for captive offshoring can still be made. The first argument is that captive outsourcing is indeed appropriate whenever a firm wishes to establish a presence in a host country that does not have a cadre of suppliers that is capable of taking on the outsourced function and/or tasks. In this case, it is better to make the investment, train the workers, and put the appropriate processes in place provided, of course, that the environment in the host country is supportive.

The second argument is best summed up by Bierce, et al [2, p. 13]: "For functions that are high risk to migrate and provide true competitive differentiation, setting up a captive model may be the most appropriate strategy. For lower-risk functions, outsourcing will most likely be the best option." Of course this argument must be tempered with the findings of Jiang, et al [7] cited above.

With regard to the second question, those companies that are currently engaged in captive outsourcing in maturing host countries may be compelled to divest (or spin off) their captives and then engage in offshore outsourcing. This seems to make sense once the captive organization has achieved scale and has an experienced and well-trained work force. Badami [1] states that BOT models should continue their growth in popularity in the short term. In the longer term, organizations will use the BOT models to enter new markets and then exercise their options to transfer if and when the host market matures.

5. Some guidelines

Based on the comparisons of strategy types in previous sections as well as emerging trends, we present a set of guidelines for choosing between captive offshoring and offshore outsourcing.

Pursuing captive offshoring appears to make the most sense when the firm:

- Wishes to follow a BOT strategy,
- Seeks to establish and keep control of operations, technology, IP, etc. at virtually any cost,
- Has the capability of extending vertical integration into a more strategic location, and/or
- Seeks to establish operations in a host country that does not have an established supplier base.

Pursuing offshore outsourcing appears to make the most sense when the firm:

- Wants to lower costs through less expensive labor, material, etc. without making a substantial investment,
- Seeks to utilize specific skills or competencies that it does not possess,
- Has the capability to manage the supplier relationship,
- Seeks to take advantage of second-tier supplier relationships that have already been established by the supplier, and/or
- Is simply not in the position to make a substantial offshore investment.

In most other situations either offshoring strategy could be considered a viable choice. The trade-off, however, would seem to be control versus investment – the degree of control over operations, technology, intellectual property, etc. will dictate the level of investment necessary. It is, however, important to keep in mind the potential benefits and risks discussed earlier for each alternative.

6. Discussion

It appears as though there will remain a mix of companies utilizing captive offshoring and offshore outsourcing. However, that mix is indeed changing to favor offshore outsourcing. The following are a few interesting observations with regard to offshoring.

- It is not unlikely that large organizations with large offshore captives that have reached scale may indeed offer their services to third party customers. This would turn their offshore operations into profit centers.
- Many organizations will "chase" expertise and create a network of offshore vendors that will be disbursed around the world. Not only will such a network allow

organizations to find the best talent around the globe, but it will allow them to buffer the risks of natural disasters as well as terrorist activities.

- Some organizations that currently only outsource back office work will begin to offshore core activities as well. We are already seeing this in medicine, finance, and engineering, among other areas.

While captive offshoring is certainly not dead, offshore outsourcing is offering significant flexibility to firms. It is opening new markets, providing new sources of skills at all levels, and it is allowing firms to operate in multiple host countries of interest without making significant capital investments. Further, we are starting to witness an era in which vendors are beginning to outsource because of the keen competition for talent around the world.

Companies electing to engage in offshore outsourcing will be forced to make greater efforts to understand the cultural, political, social, and economic environments of host countries in order to facilitate and manage offshore vendor relations. Finally, prospective vendors will have to be more carefully vetted if these "partnerships" are going to bear fruit.

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A Self-Paced Approach to Teaching Finance

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Abstract

This paper investigates the effectiveness of the Personalized System of Instruction (PSI) as a teaching method in an introductory course in investments. PSI, also know as the "Keller Plan" after its developer, Fred Keller, was introduced into the classroom in the 1960's. PSI can be described as a mastery learning methodology with specified objectives, self-pacing, small-step sequenced materials, repeated testing, immediate feedback, credit for success rather than penalty for errors, proctors, and lectures for motivation [22]. It has been shown to be an effective alternative to lecture-based teaching in many disciplines, particularly engineering and psychology. To assess the relative effectiveness of PSI, the performance of 103 students in five investments classes taught using the PSI method are compared to a sample of 25 students that took the same course under a traditional lecture-based method of instruction. Results indicate that PSI provides a useful technique for teaching investments and could be used effectively to supplement the inventory of teaching approaches used in a finance curriculum.

1. Introduction

It is widely recognized in the research literature that college students use many different approaches to learning [16][21]. For example, students may adopt a meaning-oriented approach that is directed toward an in-depth comprehension of materials to be learned; or they may adopt a superficial approach that is directed toward just being able to reproduce those materials for the purposes of academic assessment.

Studies have revealed a tendency for students to display a particular approach to learning in response to their perception of the task demands. For instance, students generally adopt a meaning-oriented approach that is proportional or consistent with more abstract forms of learning, which are demanded in higher education [24]. Also, students are motivated by the relevance of the syllabus to their own personal needs and interests [9]. Conversely, students demonstrate a superficial learning style when assessment methods allow an acceptable grade for reproduction of assigned material, especially in cases where students carry unusually heavy course loads. [4].

It has been argued that students' approaches to studying are related to their perceptions of the institutional context. Thus, an orientation toward reproduction is associated with perceptions of a heavy workload and a lack of freedom in learning, whereas a meaning-orientation is associated with perceptions of good instruction and freedom in learning [5][20][7][18]. Furthermore, the subject being studied contributes toward the learning approach that is adopted. In particular, students taking art courses are more likely than those taking science courses to display a meaning-oriented approach [6].

An open question exists, therefore, as to whether positive changes in approaches to learning can be brought about within a student group by means of the teaching methods employed. The limitations of lecture-based courses are well known [2], and it is reasonable to expect that improvements in students' approaches to learning and overall performance would occur with a more student-centered program of instruction. Based on this premise, Hambleton, Foster, and Richardson conducted a study to compare how computer science students approached learning under two methods of instruction: a conventional, lecture-based method, and a PSI method [11]. Using an

Approaches to Studying Inventory, results indicated that students had a greater tendency to adopt meaning-oriented study behavior with the PSI course than with the lecture-based course, which is consistent with the idea that appropriate interventions can bring about qualitative improvements in study approaches.

2.0 PSI

PSI, also known as the Keller Plan after its originator, Dr. Fred Keller, Professor Emeritus, Columbia University, was introduced into the classroom in 1962 at the University of Brazilia [27]. Keller's seminal article about PSI usage as a new instructional approach was later discussed in *The Journal of Applied Behavioral Analysis* [12]. PSI was initially designed to utilize what was known about the functional relations between behavior and the environment and is based upon what was known about student behavior as it is maintained by contingencies of reinforcement. PSI can be described as a form of programmed instruction that employs a highly structured, student-centered approach to course design, with the following distinguishing features:

(1) Self-pacing, which permits a student to progress through a course at a speed commensurate with his/her learning abilities and time demands.

(2) The module-perfection prerequisite for advancement, which lets students proceed to new material only after demonstrating mastery of the preceding module.

(3) The use of lectures and demonstrations as motivators, rather than the source of primary information.

(4) An emphasis on written communication between the teacher and student.

(5) The use of proctors, which permits repeated testing, immediate feedback, tutoring, and a marked enhancement of the personal-social aspect of the educational process [12][13].

PSI has been used in a variety of disciplines, institutions and academic levels [13]. There is a substantial body of literature that attests to the broad effectiveness of PSI-based courses in comparison with conventional lecture-based courses—both on objective criteria such as academic performance and on subjective criteria such as students' course evaluations [14][15].

For example, PSI was tested by Fell in an introductory nursing course with 23 students in a PSI-based course and 20 in a control group course receiving traditional instruction [8]. In this study, nursing students in the PSI group achieved significantly higher grades. In another study, Tietenberg demonstrated PSI's effectiveness involving 92 students enrolled in three sections of a microeconomics course—two sections using a conventional lecture format and the third section taught using the PSI format. [26]. The meeting duration, textbook, and body of material were held constant for all three sections. However, the PSI section had the text supplemented by written handouts that consisted of the kind of elaboration and clarification that would ordinarily occur in a lecture. The output of the testing was based upon the final examination and the course evaluation. Results indicated that the PSI method was an attractive alternative educational option. In yet another study, McLaughlin evaluated PSI's effect on the spelling performance of 10 behaviorally disordered elementary students [17]. The results included improved spelling accuracy with even further improvement when retests were permitted in the same day, improved student attitudes, and student preference for the PSI spelling program over a traditional approach.

A common element in the administration of a self-paced course is the use of students as proctors and tutors. In return for their efforts, the proctors and tutors are often awarded academic credit for the experience. To test the reasonableness of this practice, Siegfried conducted a controlled experiment to determine if the educational experience of being a proctor for an upper-level economics course is sufficiently valuable enough to justify awarding academic credit [23]. The results indicated that a semester of proctoring teaches a student more than taking the one-semester course and that credit should be awarded. In terms of the costs and benefits of proctoring, it is argued that proctoring a course takes more of a student's time than taking the course, particularly for an upper-level course [25]. Finally, the use of proctors enables the students in a PSI class to have immediate feedback on test performance.

This is particularly relevant for students termed as part of Generation X, with the expectations of an accelerated culture [3]. Research has shown students in this category are more comfortable with technology than prior generations and prefer visual and experiential forms of learning with clear and immediate relevance [1].

An important issue when using the PSI is procrastination. In theory, a method of instruction that is completely self-paced can have no deadlines so procrastination is impossible. Procrastination does arise, however, when the ideals of the PSI are confronted with the practical constraints associated with delivering courses at an academic institution [13]. It has been stated that procrastination is inevitable even in a totally self-paced course, partly because of a lack of motivation or maturity on the part of the learner, but more so because of the competing demands of conventionally taught courses being taken concurrently with PSI-based courses [19]. Unfortunately, there is evidence indicating that attempts to deal with procrastination under PSI formats tend to reduce the effectiveness of the approach [13].

Overall, several studies have shown PSI to have a number of advantages over conventional educational methods and few serious disadvantages. Based on final examination scores and tests of long-term retention (given years later), students appear to learn significantly more in a PSI-based course. This is especially true for students who would normally perform at the lower or middle levels. Studies also indicate that students enjoy their classes and tutoring sessions, and develop good habits that carry over to other courses and learning activities. Disadvantages of PSI include primarily the extra effort demanded by the instructor and the potential for a higher drop rate in some courses, particularly with students that procrastinate. Another drawback of PSI is that educators must be careful not to attribute a relatively large proportion of high grades to a lack of difficulty in the course rather than to the effectiveness of the PSI method of instruction. Lastly, administrative problems tend to be encountered when teachers prematurely attempt to use PSI to teach large sections. For the most part, PSI-type instruction has been shown to improve student learning over the traditional lecture-test approach, particularly for the average student [10].

3.0 Methodology

It seems reasonable to suggest that if a teaching methodology such as PSI can improve students' approaches to studying, then these students should outperform students that are taught using a lecture-based method of instruction. In an attempt to examine the ability to generalize the PSI tactic across disciplines, this study compares the performance of students enrolled in an undergraduate investments course using the PSI method as compared to students subject to a traditional, lecture-based approach. While similar studies have been conducted to test the relative effectiveness of these two types of instructional technology, there has been no such research in the area of business finance.

3.1 Teaching investments with PSI

The course under investigation in this study was an undergraduate investments course, offered over a ten-week term. Topics covered in this course were specifically selected to represent much of the material covered on the Series VII securities exam, because many of the students that enroll in the course ultimately find employment requiring licensure for Series VII securities. The course was segmented into the following 10 modules: 1) overview of the investment process, 2) investment alternatives, tax considerations, 3) investment companies, 4) securities markets and market indexes, 5) trading systems, 6) risk and return under certainty, 7) risk and return under uncertainty and asset pricing models, 8) bond characteristics and pricing, 9) stock valuation, and 10) option fundamentals and applications.

To facilitate learning in each of the modules, students used a standard investments text along with a study guide that contained review exercises and practice exams. When students thought they had mastered the topic(s) in a given module, they could take an exam. Passing a module exam allowed them to begin studying material covered in the next module. If they failed a module exam, they had two more opportunities to demonstrate their understanding of that module's material. Proctors were used to manage the administration and grading of exams. The exam proctors, who also served as tutors, were students that had previously taken the investments class and demonstrated an exceptional understanding of the material.

In order to exhibit a mastery of the material covered in each module, a score of 80 percent was required on an exam consisting of 50 multiple choice questions. There was also a comprehensive final exam consisting of 100 multiple choice questions, which required a score of at least 70 percent to pass. Final grades for the course were based on the number of modules that the student passed, with the final examination representing an eleventh module. Grades were assigned according to Table 1 below.

Table 1. Grading scale

Modules Passed	11	10	9	8	7	6	5
Grade	A	A-	B+	B	B-	C	D

The design of the course allowed students the freedom and responsibility to develop a study strategy that best suited their overall class schedule. For example, since there were 33 opportunities to pass 11 exams (the eleventh exam being the comprehensive final), it was possible to complete the course shortly after the middle of the ten-week term and spend the remaining time on other courses. On the other hand, students could adjust their study schedule so that they had free time in the middle of the term to devote to midterm exams or papers in other courses.

A noteworthy characteristic of this PSI-based course was the immediate feedback students received on their module exams, because proctors graded these exams immediately upon completion. As stated above, if a student passed an exam in a given module, they could begin preparation for the next module. However, if they failed a module's exam, they had two more opportunities to be retested on that module's material. This is an attractive feature of a PSI-based course, because students receive positive reinforcement when they master a subject area but are not penalized for failure.

In preparation for a retest, students had two courses of action. They could simply restudy the assigned materials for the failed module, or alternatively, they could attend a tutoring session to review the failed exam and work directly with the professor or one of the course proctors. Approximately 20 hours per week were available for face-to-face instruction and/or consultation with either a tutor or the instructor. Email was also used for personal communication with students and a web-based chat room was used for open discussions.

Several steps were taken to reduce the propensity of some students to procrastinate. One control mechanism was the use of a midterm benchmark. For the course under analysis, the benchmark date was the end of the sixth week of the ten-week term, which corresponded to the last day that the university would allow a student to withdraw from the course. If a student had not completed module six by this date, they were required to proceed to module seven and return to any unfinished modules at the end of the term. To further discourage procrastination, students were encouraged at the beginning of the term to decide on a study plan that required them to complete an average of one module per week. Students were also informed that materials in the last four modules typically required more time to master than materials in the first six modules. Finally, the students' progress was monitored and email reminders were sent to those that appeared to be falling behind.

3.2. Samples

This study compares student performance based on the final exam scores contained in two samples: a PSI sample and a lecture-based sample. All class sections in the two samples were taught during the same academic year by the same instructor, who used the same textbook and supplemental study materials. The PSI sample consisted of the final examination grades from 103 students that were enrolled in five sections of an undergraduate investments course. The students in these sections were almost exclusively in their junior year and were 20 to

21 years of age. Two of the five sections were offered in each of the first two ten-week terms of the academic year and one section was held during the third term. During the first and third terms of the academic year, two one-hour examination sessions were held daily, Monday through Thursday. Students were permitted to take an exam during either one of the daily exam periods but were limited to one exam per day. During the second term of the academic year, exams were administered during four one-hour exam sessions that were held on Mondays and Wednesdays. With this examination schedule, students were allowed to take exams for two different modules on the same day but were not permitted to retake a failed exam on the same day that the failure occurred.

The lecture-based sample consisted of the final examination grades from 25 undergraduate students that were enrolled in two sections of the same investments course. The larger of these two sections was offered at a regional campus and had an enrollment of 17 students. Ages of the students ranged from 20 to 50, with the majority of the students being over 30. The class met once per week for four hours with a 20-minute break at mid-period. Roughly 50 percent of the class time was devoted to traditional lecturing by the instructor and the remaining time was used for problem-solving activities. The second class represented in the lecture-based sample was offered during a summer term. The class met for two hours per day, Monday through Thursday for five weeks. Enrollment in this class consisted of eight undergraduate students who were either 20 or 21 years of age.

4.0 Results

Descriptive statistics for the final exam grades for the two samples are shown in Table 2. Table 2 shows that the mean of the PSI-based sample is slightly higher than that of the lecture-based sample, while the standard deviation is slightly greater for the lecture-based classes. The range of the distribution of final exam scores was wider for the PSI sample with minimum and maximum scores of 30 and 88, respectively, versus 44 and 87 for the lecture-based sample.

The null hypothesis in this study is that there is no difference in student performance in classes taught using PSI methods versus those taught using traditional lecture-based methods, where final exam scores serve as the proxy for student performance. Formally, the null hypothesis may be stated as:

H_{0i}: $\mu_{PSI} = \mu_{lecture}$,

Table 2. Descriptive statistics

PSI	Lecture
Mean 73.10	72.32
Standard Error 0.87	1.89
Median 72.00	74.00
Mode 72.00	74.00
Standard Deviation 8.88	9.44
Range 58.00	43.00
Minimum 30.00	44.00
Maximum 88.00	87.00
N 103.00	25.00

Where μ_{PSI} and $\mu_{lecture}$ are the means of the PSI and lecture-based samples, respectively. To test this hypothesis, a two-sample t test was performed. The results of the t-test are shown below in Table 3. As indicated, the null hypothesis cannot be rejected and it must be concluded that there is no statistical difference in student performance regardless of whether the method of instruction is PSI or lecture-based.

Table 3. Two-sample *t*- test

H_{0i}: $\mu_{PSI} = \mu_{lecture}$
df 24, t statistic 0.37
$P(T \geq t)$ 0.36
t critical 1.69

5.0 Summary and conclusion

Neither the most damaging arguments against PSI nor the most compelling arguments for PSI were upheld by the experiment described in this paper. PSI does not appear to be inherently more likely to improve performance in a beginning level investments course than the lecture-based method of instruction.

However, based on this exploratory study, PSI provides a promising educational option. This contribution might either take the form of replacing certain traditional courses with PSI or allowing for the adoption of one or more PSI features when using a conventional lecture course.

Additional research is necessary to fully assess the efficacy of the PSI approach and application in the finance curriculum. An extension of this research is ongoing to provide additional evidence of PSI's value as a teaching method for finance. Since this initial study included several problematic issues, such as unequal sample sizes, varied demographics of student populations, and differences in meeting times and locations, future research focuses on longitudinal testing of matched groups and an equivalent sample size design for the lecture and PSI samples. In any case, given the cost-benefit considerations extant in today's academic environment and the movement toward the increased use of distance learning modalities, future research on this topic is important.

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Improvement of Airline Industry Service Quality

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Abstract

In today's competitive environment, service quality has become more significant. A number of researches reveal the importance of assessing service quality by estimating the gap between customer expectations and perceptions. This gap is rather called service quality gap.

This paper utilizes SERVQUAL approach to perform a gap analysis of airline service quality performance against customer service quality needs in the state of Qatar. The outcomes of this study could help the airline companies close the gap, achieve better customer satisfaction, and improve service quality. Three-hundred and fifty airline service users were surveyed and their perceptions and expectations were studied to define areas of improvement in carrying out the provided services.

Prior to analysis, a reliability test (Cronbach α) has been performed and revealed that the internal consistency of the data is quite high. Then the 20 SERVQUAL gap items were factor analyzed using principal component factor analysis (for data reduction) together with varimax rotation (to have a clear factor pattern). The results of the factor analysis agreed to an extent with the original SERVQUAL factor structure.

ANOVA was utilized to test the significant difference between airline companies with respect to customer satisfaction. In addition, ANOVA was also utilized to test the relationship between the demographic characteristics and the degree of customer satisfaction. The paper presents the output for these analyses.

1. Introduction

There is an increased awareness of service quality in the developing countries these days. As one of the leading developing countries, Qatar is currently focusing on increasing the quality of the service provided in almost all of its public and private sectors. Consequently, a number of studies that assess the quality of the service provided in the state of Qatar have been made and the results are utilized for quality enhancement. This study focuses on the assessment and improvement of the quality of service provided by the airline companies in the state of Qatar. In carrying out the present study, the SERVQUAL approach was utilized. This approach that was first developed by Parasuraman et al. [16], has been widely tested and used as a mean of measuring and assessing service quality. In this approach, service quality has been defined as the discrepancy between customers' expectations and their perceptions. "Expectations" refer to customers' "Wants" whereas, "Perceptions" indicate customers' "Evaluation" of the service. The original SERVQUAL model contains five dimensions split among 22 items to measure the different aspects of service quality. The dimensions include Assurance; Reliability; Responsiveness; Tangibility; and Empathy.

- Assurance involves knowledge, courtesy of employers and their ability to convey trust and confidence.
- Reliability involves ability to perform the promised service correctly from the first time and keeping its promises.

- Responsiveness concerns the willingness of the employees to provide service to the customers (timeliness of the service).
- Tangibility includes appearance of physical facilities, tools or equipment, and employees.
- Empathy is the caring and the individualized attention the organization is giving to the customers.

Over the past decades, SERVQUAL has been modified and used to fit specific service industries. Among those are the following:

Viadiu et al. [19] used SERVQUAL approach to study the potential benefits obtained by customers of ISO 9000 quality management standards consultancy services. The paper also explored the relationship between the quality of the consulting companies and their size and the cost of service.

Li et al. [14] presented a conceptual framework to assess the quality of web based services that include electronic transaction, publication, broadcasting, and other services' applications using the SERVQUAL approach. The results of the study indicated a need to modify the SERVQUAL to better suit the context of the web based services. Several attributes and dimensions were identified to be added in the study to better assess the quality in this specific service.

Wisniewski [21] illustrated the use of an adapted SERVQUAL approach to assess customer satisfaction for those using local authority services in Scotland. The study showed that the gap approach was conceptually attractive to service managers and that the gap results were seen as being of significant operational benefit. In addition, most of the employees involved in the study decided to carry on using the SERVQUAL approach as part of their routine performance measurements.

Tan and Kek [18] presented an enhanced approach to using SERVQUAL approach for measuring student satisfaction. The proposed instrument was tested at two local universities. The analysis demonstrated that the SERVQUAL approach was very helpful in assessing students' perception and satisfaction of the education quality.

Lam [12] demonstrated the use of SERVQUAL approach for measuring patients' perceptions of health care quality in Hong Kong. It examined the applicability of this tool to the health care sector; however, the proposed five dimensions of SERVQUAL were not confirmed. The study shows that the improvements were still needed in hospitals in Hong Kong especially in the area of timely, professionally, and completed service in addition to showing individual attention to customers. This study helped the hospitals top management to focus on patients in the service delivery.

Wilkins et al. [20] presented the use of SERVQUAL approach in the context of luxury and first class hotel sectors. This paper helped the hotel managers to focus on those quality attributes that customers find important and thus achieve better customer satisfaction.

Lee and Yom [13] compared the nursing service quality, satisfaction, and the intent to revisit the hospital as perceived by patients and nurses in Korea. In doing so, Lee and Yom utilized the SERVQUAL approach that showed that the overall nurses' expectations and perception were higher than those of the patients. In addition, the perception was relatively lower than expectation and thus the gap between expectation and perception for both patients and nurses needed to be reduced to improve the poor nursing care quality.

Lai [11] utilized SERVQUAL approach to measure user satisfaction with enterprise application utilized by E-business. Lai also measured E-business employees' perceived service quality to be able to diagnose and improve it. The results of the study encouraged practitioners and researchers to use the same approach in comparing and studying the service quality across several departments, businesses, and industries.

Akbaba [2] investigated the service quality expectations of business hotels' customers and examined the validity of the SERVQUAL approach. The results of the study confirmed – with minor difference- the five dimensional structure of the SERVQUAL and showed that the "Tangibles" is the most important factor in predicting business travelers' overall satisfaction. It emerged as the best predictor of the overall service quality.

Fernandez and Bedia [7] examined whether the hotel classification system (five category system using stars) is a good indicator of hotel quality. This study utilized SERVQUAL approach to measure service quality. The results of the study confirmed that the ranking by category did not agree to ranking by quality. This was because quality is associated with the delivery of a service according to client expectations more than its established category.

Kassim and Bojei [10] assessed service quality gap in telemarketing industry in Malaysia using the SERVQUAL approach. The study determined the service attributes that can be used to promote telemarketing services. In the analysis of the gap between the customer perceptions and expectations, the reliability tended to have the largest gap. This means that customers appear not to be getting what they expect from their telemarketing service provider. This was an area that needs more focus from the service provider companies if they seek better customer satisfaction.

In addition to all of the above researches, other researchers had also applied SERVQUAL to evaluate service quality for different sectors like security brokerage firms [15]; dental office [9]; dental school patient clinic, business school placement center, tire store, and acute care hospital [5]; book store, long distance telephone company, pizza shop, movie theater, and internet provider [3], wild life safari (and an information systems department [17].

SERVQUAL has been criticized from both the theoretical and operational point of view [4]. However, many authors are still successfully utilizing such approach as the most appropriate method to assess customer satisfaction [6].

Although the SERVQUAL approach had been used extensively in most service industries, there had been limited research that addresses the use of such approach to assess the quality of service provided by the airline companies.

This paper developed a quality assessment framework for airline service quality through the alteration and use of the original SERVQUAL approach. The authors utilized SERVQUAL methodology to perform a gap analysis of airline service quality performance against customer service quality needs in the state of Qatar.

Section 2 of the paper shows the research methodology, followed by the analysis section and the limitation and future research section, and finally the conclusion section.

2. Research methodology

2.1 Questionnaire design and data collection

A self administered questionnaire was designed, developed, and distributed on potential airline customers in the state of Qatar. The returned questionnaire data was coded and entered into statistical package SPSS for windows version 13 for analysis. The questionnaire is composed of three sections. The first section includes demographic questions (age, education, gender, income, reason for traveling …etc.). The second part of the questionnaire is devoted to 20 statements that are related to customers' expectations of the quality of the airline services. The last section encompasses another 20 statement that assess the customers' perceptions of the service quality provided by the airline company that they are using the most. The 20 statements in section 2 and 3 are very similar to the 22 statements of the original SERVQUAL approach except that two of the twenty two questions were removed due to the fact that they are very ambiguous when translated into the Arabic version of the questionnaire.

A pilot survey was conducted to validate and improve the questionnaire in terms of formatting and wording clarity. A total of 50 questionnaires were distributed on potential airline customers. 50 responses were received (100% response rate) and analyzed. Some of the respondents had concerns on the wording of the questionnaire. This allowed the research team to improve the language of the questionnaire before distributing it on the rest of the potential customers. The survey was undertaken using the improved version of the questionnaire during the end of year 2007. Respondents were asked to indicate their expectations and perceptions for each of the 20 items in the questionnaire using a five-point Likert scale, with "1" indicating "strongly disagree" and "5" indicating "strongly agree".

The questionnaires were distributed to customers in four of the biggest travel companies in the state of Qatar. The respondents were requested to fill out the questionnaire in the company before going home. The research team was present during the filling process to answer any questions and clear up any ambiguity that might be in the questionnaire. Out of the 400 questionnaires that had been randomly distributed, 350 were correctly completed and collected from the airline customers present at the four travel companies at the time of the study.

2.2 Demographic characteristics

The sample consisted of 350 participants; approximately half of them were women. About 48% of the participants are in the age category between 18 and 30 years old, 35% are in the age category between 31 and 40 years old, and above 40 years old account for 17% of the sample. University degree category has the highest percentage among all categories in the education variable with 52%, while the least common category is the less than high school with 5.1%. Family income was distributed across above 5000$ per month (29%), between 3000$ and 5000$ per month (28%), and between 1000$ and 3000$ per month (33%). Participants who have an income below 1000$ per month constitute only 10 %. More than two third of the participants, their average number of trips per year is less than or equal five trips per year. Purpose of traveling for participants varies from visiting (39%), working (30%), and tourism (25%). A very small percentage was traveling for the purpose of education (4%) and medical trips (2%). Approximately half of the participants are having a frequent flyer (Mileage) program. "Qatar Airways" was the airline company most commonly used (64%), and the remaining customers were relatively evenly distributed across "Egypt Air" (10%), "Emirates Airlines" (8.3%), "Foreign Companies" (8%), and "Others" (9.1%). "Foreign Companies" category includes companies such as: Lufthansa, Cathy Pacific, KLM, British Airway, Air France, and Singapore. The "Others" category consists of companies that have small portions of our sample, so they are added in one category. This category has airlines' companies like Saudi Airline, Gulf Air, Jordanian, Middle East Airline, Syrian, and finally Etihad Airways. Thereby it seems that "Others" category includes companies from middle east region. Therefore, they will have different characteristics than "Foreign Companies".

3. Analysis of results

The analysis consists of factor analysis and its significance. Then, reliability analysis is included to check if the new dimensions resulted from the factor analysis is a good representative. Finally, the authors used the new dimensions in a gap analysis to point out areas of improvement. This would help in upgrading the airline service quality, especially in the contemporary world of strong competitions between airline service providers.

3.1 Factor analysis

Factor analysis was used to test the dimensionality of a set of variables. It can be viewed as a data-reduction technique by reducing a large number of overlapping measured variables to a much smaller set of factors. This technique is built upon identifying factors that are statistically explaining the variation among measures [8].

In the below factor analysis, the principal component techniques was used, which requires three stages, factor extraction, factor rotation, and factor scoring. The primary objective of the first stage is to make an initial decision about the number of factors underlying a set of measured variables based on the combination of the following: The proportion of the sample variance explained; subject matter knowledge; reasonableness of the results. The goal of the second stage is twofold: one is to rotate factors to make them more interpretable, and second to take decisions about the number of underlying factors.

Last but not least, is the scoring stage where the solution obtained from the rotated matrix and the scored coefficient matrix are compared to ensure having the loading group in the same manner. Otherwise, the first two steps have to be repeated using other number of factors.

In our analysis, the factor extraction, rotation, and scoring were performed as follows:

The twenty expectations and perceptions questions were utilized. The difference between the perceptions of the participants concerning the airline service provider they commonly used and their expectations of service quality was obtained. This difference between these two terms is called "Gap Scores (P-E)".

The factor extraction required taking factors that have eigen values greater than one. Therefore, five factors were extracted from the twenty gap scores (P-E). The five-factor solution was rotated using a varimax rotation to yield interpretable factors. The rotated five-factor solution did not have a clear pattern. A four-factor solution was suggested to be used instead. But after scoring of these four factors, the component score coefficient matrix appeared not to preserve the rank of factors as in the original rotated matrix and there were similar weights over several factors in one of the questions "Question 11". Thus, this four-factor solution cannot be used, because Question 11 "Airline staff always willing to help passengers" has the same load over several factors due to that it can be written in terms of the other variables. This question will be removed and the four factors will be extracted using nineteen gap scores only. The new four-factor solution was rotated using the varimax rotation then it was scored. Component score coefficient matrix of the new factors including the 19 variables preserved the rank of the rotated matrix of the new factors. The rotated solution as in Table 1 yields four interpretable factors, explaining 60 % of the total variance.

The rotated factor loading matrix (Table 1) gave us a chance to suggest the labeling of the four dimensions through identifying in each factor the variables with the highest loads on this factor. By looking at Table 1, we can see that factor 1 has 5 variables that have the highest load which are highlighted in column 1 (component 1). Same goes for factor 2 (6 variables), factor 3 (4 variables), and factor 4 (4 variables).

TABLE 1. FACTOR LOADING MATRIX

		Component			
		1	2	3	4
A14	The passengers feel safe in their transactions with airline staff	.77	.27	.06	.10
A14	The airline staff are consistently polite with passengers	.74	.18	.16	.22
A13	The airline staff provide clear and precise answers for the passengers' inquires which instill confidence in passengers	.69	.23	.22	.16
A16	The airline staff have the knowledge to do their job well (professional)	.60	.18	.15	.34
Rs12	The airline staff is never too busy to respond to passenger request	.58	.37	.15	.21
Rs9	The airline staff inform passengers when the services will be performed	.23	.72	.08	.03
Rl8	The airline companies keep error free record	.12	.72	-.00	.19
Rl7	The airline staff provide their services at the time they promise to do so	.25	.64	.27	.03
Rl6	The airline staff are dependable	.24	.60	.27	.22
Rl5	The airline staff show a sincere interest in solving passengers' problems	.42	.55	.34	.1
Rs10	The airline staff provide prompt assistant to the passengers	.50	.52	.2	.19
T2	Airline offices are visually appealing	.02	.15	.78	.08
T3	The Airline employees are well dressed and neat in appearance	.23	.03	.77	.05
T4	The physical appearance of the airline company indicates the kind of services provided	.23	.22	.65	.22
T1	The airlines should have up to date equipment	.13	.19	.64	.24
E17	The operating hours of the airline offices are convenient to passengers in addition to high frequency of flights	.15	.06	.22	.7
E18	The airline company including staff give passengers personal attention	.41	-.02	.14	.68
E20	The airline staff understands specific needs of passengers	.14	.37	.05	.65
E19	The airline staff have the passengers best interest at heart	.29	.43	.25	.51

The authors described the obtained 4 factors (dimensions) as follows:

- Dimension 1: Assurance Responsiveness
This dimension is associated with the employees' knowledge to do their work well and their ability to pass on trust to customers though immediate service and useful help.
- Dimension 2: Reliability Responsiveness
This dimension is associated with employees' ability to perform the promised service dependably without any hesitation.
- Dimension 3: Tangibles
This dimension is associated with the physical appearance of the companies' facilities which indicates the kind of service provided.
- Dimension 4: Empathy
This dimension is associated with the personal attention given to the passengers.

The responsiveness was divided among the first two dimensions because the true meaning of responsiveness was not clear to the participants. The participants understood in the first dimension that knowledge of employees and their ability to convey trust and confidence (assurance) should be accompanied with willingness to facilitate punctual service to customers (responsiveness). The same thing happened for the second dimension. Participants presumed that the ability of the employees to perform the service accurately and reliably (reliability) should be associated with their ability to offer prompt service (responsiveness).

Therefore, the obtained dimensions agreed -to a certain extent- with the original dimensions of SERVQUAL scale proposed by Parasuraman et al. [16]. The SERVQUAL was developed in a Western environment, any difference between the resulted dimensions and the original SERVQUAL dimensions is due to cultural orientations that affect overall expectation with regard to service quality.

In the following analysis, it should be specified that a positive gap indicates that perceptions of customers are greater than their expectations; which means that the service that is provided is good, whereas a negative gap indicates that perceptions of customers are smaller than their expectation; which means that they expect a better quality than what they get.

3.2 Reliability analysis

A reliability test is used to examine whether the four gap factors are reliable. The Cronbach alpha based on standardized items for the four factors was .912, which is quite high. Therefore, the four gap factors are reliable.

3.3 Gap analysis and identification of areas for improvement

In this part of the analysis, one-way analysis of variance (ANOVA) will be used extensively. This section is divided into three parts as follows:

- ANOVA is utilized to study the degree of customer satisfaction with the service provided by the airline companies. The gap scores (P-E) will be used as the dependent variable, whereas, the airline company that the customer is using the most will be the independent variable. This is shown in section 3.3.1.
- ANOVA is used to study the relationship between the demographic characteristics and the degree of customer satisfaction measured in the gap between perception and expectations (P-E). This is shown in section 3.3.2.
- ANOVA is used to study the ticket price effectiveness from the customers' point of view. This is shown in section 3.3.3.

The above analysis requires first to test for homogeneity. This test checks whether there is constant variability between different categories using alpha equal to 0.1. If the test reveals that the variability is not constant, the Welch statistic will be used instead of the

ANOVA, i.e., if the test of homogeneity of variances is significant, then the Welch statistic will be the measure utilized in this case.

The next step is to check the significance of the test carried out, using the test p-value. Alpha (0.1) is compared with the p-value. If the p-value is less than alpha, then the test is statistically significant. This means that there exists at least one category of the dependent variable significantly different than the others. Thereby, multiple comparison tests will be employed to find out which category has the significant difference. If ANOVA is utilized in the previous step, then LSD test will be employed, because it assumes the equality of variances. Otherwise, Dunnett's c test will be used, as it assumes inequality of variance, which is the case of the Welch statistic.

Table 2 Degree of customer satisfaction

Factor	P-value
One: Assurance Responsiveness	0.422
Two: Reliability Responsiveness	.029
Three: Tangibles	.082
Four: Empathy	.194
Overall Score	.001

3.3.1 Degree of customer satisfaction from the service provided by the airline companies

This part of the analysis investigates the customer satisfaction with respect to each quality dimension and the overall customer satisfaction from the service provided by the airline company that they are using the most. Table 2 summarizes the results obtained from different tests that are used. The customer satisfaction data from different companies was tested using ANOVA or the Welch statistic, depending on the significance of the test of homogeneity.

The Welch statistic was significant for the second dimension (reliability-responsiveness). In addition, Welch shows that the overall customer satisfaction differs from one company to the other. ANOVA was statistically significant for the third dimension (tangibles). Finally, the degree of customer satisfaction of different companies is not different with regard to the first dimension "assurance responsiveness" and the fourth dimension "empathy".

Multiple comparisons test was performed to find out the category/categories of the independent variable (companies) that is/are significantly different than the other categories with respect to the satisfaction at a significance level of 0.1. Table 3 explains the post hoc results for this part of the analysis.

Table 3 Post hoc test results for companies with respect to customer satisfaction

Factor	Category I	Category J	Significant Mean Difference (I-J)
Two: Reliability Responsiveness	Qatar Airlines	Others	.440175
Three: Tangibles	Qatar Airlines	Egypt Air	.318676
Three: Tangibles	Qatar Airlines	Others	.431047
Overall Score Satisfaction	Qatar Airlines	Egypt Air	1.32875
Overall Score Satisfaction	Qatar Airlines	Others	1.35846

Table 3 shows that "Qatar Airlines" has more advantage over "Others" in satisfying customer needs. It has a good performance regarding reliability-responsiveness, tangibles and the overall customer satisfaction over "Others" companies. It also has higher overall customer satisfaction over "Egypt Air". The satisfaction of customers with "Qatar Airlines" tangibles is more than what is available for "Egypt Air" tangibles. In addition to that, the overall customer satisfaction is greater for "Qatar Airlines" than for "Egypt Air". So customers think that "Qatar Airlines" provides a better overall service quality than what "Egypt Air" and "Others" provides to its customers.

3.3.2 Relationship between the demographic characteristics and the degree of customer satisfaction: This is the second part of the analysis that discusses the relationship between the demographic characteristics (age, education, family income, average number of trips, purpose of traveling, and frequent flyer membership) and the degree of customer satisfaction. In this part, the demographic characteristics are used as the independent variable, whereas the degree of customer satisfaction measured in the gap between perception and expectations (P-E) is used as the dependent variable.

Table 4 below includes the significant p-values obtained from the ANOVA or Welch test. The table shows the demographic variables that have significant relationship with either each quality dimension or with the overall satisfaction score. Missing values reveals the absence of significance relationship.

In what follows, the output shown in Table 4 will be discussed in details:

The variables gender; age; and number of trips did not have any significant relationship with any of the quality dimensions or the overall customer satisfaction score. That means that being a male/female; young/old; or frequent/rare traveler did not change the level of satisfaction. Moreover, the level of education has significant relationship with assurance-responsiveness and empathy dimensions as well as with the overall customer satisfaction score. Nationality of the customers and being a member in the frequent flyer program significantly influences their degree of satisfaction. The relationship between these characteristics and assurance-responsiveness; reliability-responsiveness dimensions are significant. It was found that the assurance-responsiveness quality dimension and the overall customer satisfaction have statistically significant relationships with the family income. Finally, the relationships between the two quality dimensions (assurance-responsiveness and tangibles) and reason for traveling are significant. This relationship explains that different reason of traveling for customers will have an effect on their satisfaction with airline service provided.

Multiple comparisons test was again performed to find out the category/categories of the independent variable (demographic characteristic) that is/are significantly different than the other categories with

Table 4. The relationship between customer satisfaction anddemographic characteristics

Demog. / Factor	Educ.	Nat.	Inc	Reas. For Travel	FreqFly
Assur-Resp.	.022	.000	.001	.105	.045
Rel. Resp.		.003			.02
Tangible				.068	
Empathy	.102				
Overall Satisf.	.003		.061		

**Empty cells for insignificant relationship.*
* Values shown are for significant p-values.

respect to satisfaction at a significance level of 0.1.

According to the previous findings from Table 4, the comparisons were obtained as in Table 5. The last column of Table 5 shows the significant mean difference values between the two categories (I-J). Positive value means that category I is more satisfied that category J and vise versa.

From the Table, a number of comments can be grasped, most importantly is that:

education raises the awareness and the expectation of customer from the provided service. High school customers are more satisfied than university graduate. Moreover, family Income have also influence on overall customer satisfaction. Customers who have family income between $1000 and $3000 are not easily satisfied compared to customers who obtain more than $5000. This is due to the fact that the first category usually uses economy class while traveling as compared to the business/first class used by the other category (income more than $5000).

3.3.3 Price Effectiveness: This section of the analysis is outside the scope of the SERVQUAL approach. The customer was asked a question about his/her expectations and perceptions concerning the competitive price of the airline ticket. From the analysis, it was found that there is no significant difference (p-value =0.398) between customers of different companies with respect to availability of competitive prices for the ticket. This means that all customers think that the company that they are using is considered competitive with respect to the price. The second step of this analysis requires establishing the relationship between the different demographic characteristics and the availability of tickets with competitive prices. The output of this analysis is shown in

Table 5. Post hoc for the different demographic characteristics with respect to customer satisfaction

Factor	Demog. Charact.	Cat. I	Cat. J	(I-J)
Assur. Resp.	Education Level	High School	Univ. Graduate	.36
Assur. Resp.	Nationality	Gulf (Non-Qatari)	Arab (Non-Gulf)	.56
Assur. Resp.	Nationality	Gulf (Non-Qatari)	American European	.67
Assur. Resp.	Nationality	Gulf (Non-Qatari)	African or Asian	.50
Assur. Resp.	Family Income	0-$1000	$1000-$3000	.49
Assur. Resp.	Family Income	0-$1000	$3000-$5000	.38
Assur. Resp.	Family Income	$1000-$3000	More than $5000	-.43
Assur. Resp.	Reason for Traveling	Education	Visit	.50
Rel. Resp.	Nationality	Gulf (Non-Qatari)	American and European	-1.0
Rel. Resp.	Nationality	Gulf (Non-Qatari)	African or Asian	-.71
Rel. Resp.	Nationality	Arab (Non-Gulf)	American and European	.60
Tang.	Reason for Traveling	Visit	Tourism	-.31
Tang.	Reason for Traveling	Work	Tourism	-.31
Tang.	Reason for Traveling	Tourism	Medical	.79
Emp.	Education Level	High School	Post Graduate	.42
Overall Satisf.	Education Level	High School	University Graduate	.91
Overall Satisf.	Family Income	$1000-$3000	More than $5000	-.66

Table 6 below. The shown values are the p-value between the dependent variable (price effectiveness) and the independent variables (education; nationality; and reason for traveling). The rest of the demographic characteristics show no significant relationship with the dependent variable.

Post hoc multiple comparisons shows that less than high school customers are highly satisfied from the ticket prices. They are more convinced with ticket prices than high school, university graduate, and post graduate.

Table 6. Price effectiveness versus demographic characteristics

	Educ.	National.	Reason for Traveling
Price Effect.	.005	.000	.041

On the other side, high school customers are more convinced with the ticket prices than university graduate or post graduate customers. This can be attributed to the fact that customers with the high school or below education level are irrational in making their purchasing decision based on the best value of money.

In addition, the multiple comparisons analysis also shows that nationality affect the satisfaction from ticket prices. Qatari customers are more persuaded with ticket prices than Arab (non-gulf), and American and European customers. Gulf (non-Qatari) customers are convinced with ticket prices than Arab (non-gulf), and American and European nationalities. Finally, African or Asian are more satisfied with ticket prices than Arab (non-gulf), and American and European nationalities.

4. Limitations and further research

No data were collected of the perceptions and expectations of the airline companies' employees. This could be performed in a later study with a comparative analysis between the customers and the employees' degree of satisfaction.

After the results of this study reached the airline companies top management, a longitudinal study (after one years) could be performed on the same sector of customers to ensure that the quality of service has been improved using the output of this study.

5. Conclusions

This study has contributed to the theoretical and methodological advancement of service quality and airline industry literature by pinpointing areas of improvement that can be tackled by airline companies' top management in order to achieve better customer satisfaction.

The major conclusions of this paper are:

- The obtained dimensions (after factor analysis) for airline customers agreed - to a certain extent- with the dimensions proposed in the original SERVQUAL.
- Qatar airways are more successful in satisfying customer needs than Egypt air and Others companies.
- The overall customer satisfaction in airline industry is highly affected by their educational level and their nationality.
- The satisfaction of customers from ticket prices is significantly different with respect to educational level and nationalities.

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A Dynamic Simulation Study to Assess the Impact of Collaboration on the Performance of a Supply Chain Subject to a Variety of Demand Environments

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Abstract

It has been well established that collaboration among members of supply chain yields lower inventory levels and increased profits across the supply chain. This research attempts to define the demand environments under which collaboration would be particularly beneficial. In this regard, a System Dynamics Model of a three echelon automotive parts supply chain is constructed and its performance is analyzed under various demand scenarios. The results indicate that supply chains faced with variable demand environments that are predictable offer the best potential for positive outcomes from collaboration.

1. Introduction

Consumers in today's society expect the availability of a wide variety of products at a low cost. The retail sector at the same time is experiencing a misalignment of supply and demand; shelves are out of stock of items in demand and yet have excessive inventories. The main reasons for this are erroneous forecasts across the supply chain.

Different functions within a firm have often been involved in the development of forecasts based on a variety of information sets (Stank, Daugherty, and Autry, 1999). The problems associated with independently developing forecasts within a firm are magnified when trading partners also develop independent forecasts. Individual firms have their own set objectives and develop forecasts based on their respective pools of inventory (Schenck, 1998). Hence, every member of the supply chain develops independent estimates of demand and assumes the responses of other members, resulting in mismatch of supply and demand (Butler, 1999). Collaboration plays a very important role in combining the information in multiple forecasts into a single coordinated plan.

Collaboration enhances inter-enterprise as well as intra-enterprise synchronization of information. It implies sharing of data, information, forecasts, and functions with a goal of creating a win-win situation for all the members of a supply chain. It is not a novel business approach, since companies at times exchanged information and product data with their trading partners. Firms have been using systems that deal with specific business issues addressed from diverse domains such as customer relationship management (CRM), enterprise resource planning (ERP) and advanced planning and scheduling (APS) (Ashayeri and Kampstra, 2003). Over the past decade various collaboration techniques have been applied, these include, EDI (Electronic Data Interchange), VMI (Vendor Managed Inventory), QR (Quick response), ECR (Efficient consumer response), CM (Category Management) and CR (Continuous Replenishment)

Collaborative Planning Forecasting and Replenishment (CPFR) is an approach that has been developed from the abovementioned collaborative techniques that focus on integration of supply and demand planning, and addresses some of the drawbacks of past initiatives such as independent forecasting. The goal is for the supply chain members to operate as an integrated system to satisfy customer demand (Attaran, 2004).

This paper evaluates the effects of collaboration on inventory, service levels, sales and profit across the supply chain under different demand environments. The purpose of this study is to identify demand environments where collaboration is particularly beneficial, so that firms exposed to such demand environments may be motivated to collaborate across the supply chain.

The next section reviews the pertinent literature on collaboration, following that we present the contextual environment for the study, followed by the results of a System Dynamics study of the effects of supply chain collaboration under different demand environments.

2. Past studies on collaboration

Research investigating the impact of collaboration on supply chain performance, can be categorized as (i) *conceptual research,* which defines the introductory concepts, benefits and limitations of CPFR (e.g., Barratt and Oliveira 2001, McClelan 2003, Seifert 2003, and VICS 1998), (ii) *empirical research,* which analyzes inter-organization collaborations and assesses current levels of involvement in CPFR (e.g., Skjoett-Larsen et al. 2003, and Stank et al. 1999), (iii) *case study based research,* which discusses the concerns of supply chain members involved in collaboration (e.g., Luc 2003, and Miller 2001), (iv) *mathematical/analytical modeling based research,* which investigates the quantification of the "bullwhip" effect, and the performance of supply chain members (e.g., Chen 1998, Park 2002, Ragunathan 1999, and Lee at al. 1997), and (v) *simulation modeling based research,* that attempts to understand supply chain behavior and the effectiveness of e-collaboration tools (e.g., Ovalle and Marquez 2003, Wei and Krajewski 2000).

Ganeshan et al. (2001) investigated the sensitivity of supply chain performance under the influence of different inventory parameters such as forecast errors, mode of communication between the echelons, and re-planning frequency. The study revealed that forecast errors contributed to an increase in cycle time, and a decrease in service levels. Aviv (2001)(2002) develops a model for a single retailer and a single supplier that provides insights into the impact of localized and collaborative forecasts on supply chain performance. Zhao et al. (2002) conducted a simulation study with a model of a single supplier and multiple retailers, to examine the impact of different forecasting models on supply chain performance and the value of information sharing. They reported that information sharing (especially future order information) had a significant impact on supply chain performance and total supply chain costs. Wilson (2002) evaluated the impact of operational improvements, primarily reduction in transit time, and reduction in production lead time on inventory fluctuations in three different inventory management systems: traditional, VMI (vendor managed inventory), and a variant of CPFR. The study demonstrated that inventory fluctuations were considerably reduced for the manufacturer when internal operations were improved. Chatfield et al. (2004) conducted several experiments to study the effects of stochastic lead times in supply chains, and the impact of information sharing in reducing the "bullwhip effect" (BWE). Their research revealed that variance amplification, which is an integral part of the BWE, could be reduced by nearly 50% through sharing of information. Aviv (2007) develops a model for a single manufacturer and single retailer, to assess the potential benefits of collaboration. Their conclusion is that the manufacturer has to be agile to gain the benefits of collaboration.

Almost all the studies presented in the literature address two echelon systems and lack a systems viewpoint neglecting to consider the complex interactions across the supply chain. The model presented in this paper considers these interactions and presents a more realistic three echelon model covering suppliers, distributors and retailers.

3. Contextual environment of the study

The contextual environment represented in this study is that of an automotive service parts supply chain, as depicted in Figure 1, (Shaw et al, 2003). The retail sector represents entities, such as authorized dealers, outlets for service parts, etc. that store a variety of service parts for various automotive segments (Compact, Mid-size, Full size, SUV's, and Minivans). Auto dealers normally lie at the end of a complex automotive supply chain that carries thousands of part numbers, ranging from small nuts to big transmissions and engines. Since dealers cannot possibly keep everything in stock, efficient service parts management is essential to lower the inventory costs and to keep high service levels. A parts distribution center (PDC) supplies parts to the dealers in a specified region. A PDC can normally provide same-day delivery of critical parts to dealers. Other items may arrive as weekly or biweekly stock orders. A redistribution center (RDC) supplies parts to PDC and carries much more inventory than a PDC.

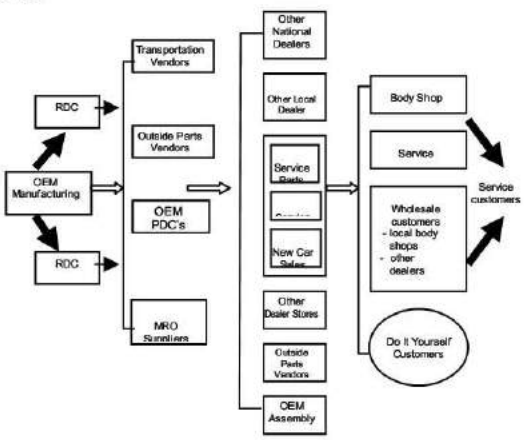
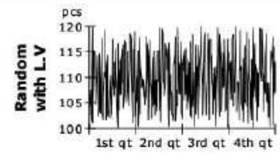
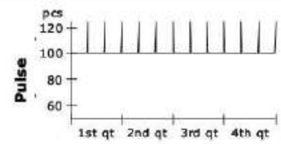
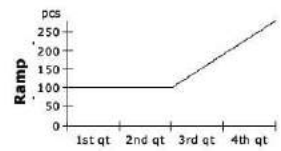
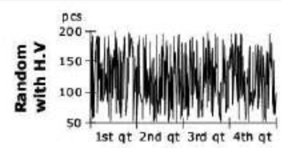
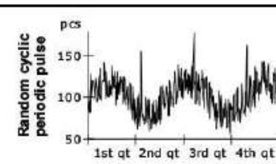
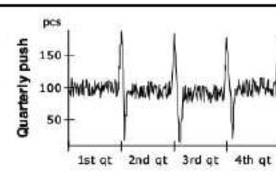
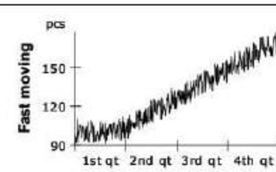
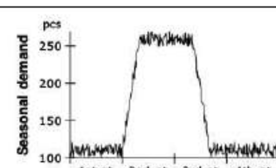


Figure 1: Automotive Service Parts Supply Chain (Shaw et al, 2003)

3.1 System Dynamics model

The System Dynamics methodology (Forrester, 1961) is used to create a computer model of the system under study using the software, Studio 7, from PowerSim Software (www.powersim.com). The model was run to examine the dynamic interactions of system elements under various scenarios. The block diagrams shown in Appendices (1A-1C) depicts the 3-echelon baseline model of the system using the graphical feed back loop representation framework of System Dynamics. The baseline model reflects "traditional supply chain" management principles. The term, "traditional supply chain", in this paper, represents minimal collaboration among the three echelons, i.e. upstream supply chain members receive only order information from downstream partners and each echelon makes forecasting, ordering and inventory decisions independently. Perusing the block diagram representations in each sector clarifies the interaction of elements within each sector and across the supply chain. For example in Appendix 1 A the block diagram of the retail sector is displayed. Customer demand, in the retail sector, triggers policy based events that affect the performance of the whole supply chain. In the retail sector, as in other sectors, it is assumed that backordering is not allowed and unfulfilled demand is lost. The retailer follows a simple ordering policy; an order is generated at a specified frequency and its size is based on the difference between actual and desired inventory positions. The actual inventory position depends on the current level of inventory, goods in transit, and on order. The desired inventory position is defined by the lead time demand, order frequency cycle and the safety stock. The shipment from the parts distribution center arrives at the retailer, after a specified lead time, which is represented as a delay in the model. The flow of shipments from the distributor increases the level of 'goods in transit"; this level is reduced when the products are received by the retailer. It is assumed that partial shipments are allowed with no restriction to order size. The ordering policies and flow of goods into the other echelons, such as, between the PDC (distributor) and RDC (supplier), are similar to that of the retail sector and are represented likewise in the block diagrams shown in Appendix 1B and 1C, respectively. It is assumed that there is no capacity constraint for product supplies to the RDC. The parameters used in the simulation model reflect masked values of real life data from an automotive service parts supply chain. Verification and validation of the model were realized by evaluating parameter sensitivity and dynamic model behavior.

Table 1: Demand Patterns used in TIM & CPFR Based Models

SN O.	Demand Pattern	Description	Graph
1	Random with low variance	Fairly constant and predictable (low variation between 100 & 120 units).	
2	Pulse	Remains constant (100units/day) for every 30 days and then there is a sudden spike of 25 units	
3	Ramp	Remains constant for first 180 days followed by constant growth (1 unit/day)	
4	Random with high variance	Varies randomly with high variation between 50 & 200 units	
5	Random - cyclic with periodic pulse	Varies between 75 & 125 units, followed by Sine wave and with periodic pulse every 100 days	
6	Quarterly push	Before the end of every quarter the demand rises and comes back to equilibrium at the beginning of next quarter	
7	Fast Moving	The demand is increasing at a rate of .25pcs/day after 75 days	
8	Seasonality	The demand rises at the end of every quarter , then levels out, drops back and then stabilizes	

3.1.1 Scenarios

The behavior of the system was examined under various demand scenarios, such as random with low variance, pulse, ramp, random with high variance, combination (random cyclic with periodic pulse), quarterly push, fast moving and seasonal demand. These demand patterns are illustrated in Table 1.The demand patterns represented are not unusual, in fact, patterns like quarterly push and seasonal are often encountered in an automotive service parts environment. The System Dynamics model of the traditional supply chain/inventory management (TIM) model was also modified to observe the impact of collaboration on the performance of the supply chain subject to the various demand patterns. The primary modifications are illustrated in Figure 2.

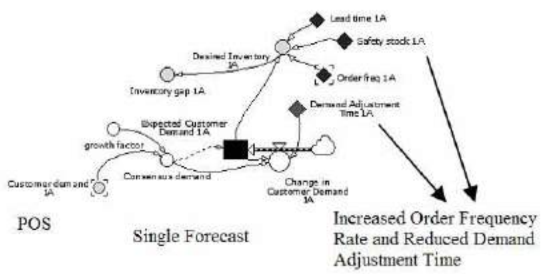


Figure 2: Primary Concepts of Collaboration represented in the Model

One of the key principles underlying collaboration is dynamic information sharing among supply chain members. In line with above perspective, the model has a consensus demand forecast for the entire supply chain and all echelons receive customer demand information at the same time, whereas in the TIM based model the upstream members of the supply chain (RDC and PDC) only receive order information from their downstream customers. Collaboration initiatives, such as CPFR, result in a single common forecast that is based on a mutually agreed plan. With POS information available to suppliers, they are able to supply more frequently i.e. "increased order frequency rate", and "reduced demand adjustment time". Since suppliers are able to respond to the demand better, this results in reduced inventory across the supply chain. Supply chain members practicing CPFR share replenishment plans, and identify and resolve exceptions. The resolution of exceptions and consensus based plans are emulated in the simulation model with a variable "growth factor". The consensus demand is determined as a function of the growth factor and the actual customer demand obtained from Point of Sale (POS) data, as shown above in Figure 2.

4. Results of the System Dynamics study of the effects of collaboration on performance

The performance of the supply chain, under the different demand scenarios, is evaluated using the models described in the previous section. The performance measures used include inventory, service levels, sales and profit. The results indicating the percentage improvement of the performance measures under the different demand scenarios are summarized in Table 2.

The simulation results reveal that performance of a supply chain operating under the principles of collaboration, such as in CPFR improve the performance of the supply chain for almost all demand scenarios. The only exception gleaned from the simulation was that when there was high "unpredictable" variability in the demand patterns, such as in demand patterns classified as "random with high variance" the service level, measured by the order fill rate, was lowered slightly under CPFR for the supplier and distributor. This could be explained by the fact that collaboration tends to lower inventory buffers across the supply chain, resulting in inadequate protection against random high variance demands. The largest gains with collaboration were realized under demand patterns that can be predicted and planned for, such as seasonal and ramp demands.

Table 2: Impact on Supply Chain Performance Measures

		Low Variance	Pulse	Ramp	Random High Variance	Random Cyclic Pulse	Quarterly Push	Fast Moving	Seasonal Demand
Retailer	TIM								
	CPFR	19%	4%	2%	1%	6%	18%	8%	32%
Distributor	TIM								
	CPFR	25%	16%	11%	32%	31%	40%	38%	59%
Supplier	TIM								
	CPFR	36%	30%	29%	38%	39%	37%	43%	57%

Impact on Inventory levels (a)

		Low Variance	Pulse	Ramp	Random High Variance	Random Cyclic Pulse	Quarterly Push	Fast Moving	Seasonal Demand
Retailer	TIM								
	CPFR	9%	16%	28%	7%	11%	11%	18%	23%
Distributor	TIM								
	CPFR	16%	21%	42%	13%	17%	21%	22%	27%
Supplier	TIM								
	CPFR	20%	14%	50%	27%	30%	19%	28%	8%

Impact on Sales (b)

		Low Variance	Pulse	Ramp	Random High Variance	Random Cyclic Pulse	Quarterly Push	Fast Moving	Seasonal Demand
Retailer	TIM								
	CPFR	13%	20%	25%	7%	11%	16%	21%	42%
Distributor	TIM								
	CPFR	35%	32%	70%	41%	34%	66%	57%	62%
Supplier	TIM								
	CPFR	29%	21%	62%	20%	81%	40%	50%	66%

Impact on Profit Levels (c)

		Low Variance	Pulse	Ramp	Random High Variance	Random Cyclic Pulse	Quarterly Push	Fast Moving	Seasonal Demand
Retailer	TIM								
	CPFR	9%	15%	22%	6%	10%	10%	17%	15%
Distributor	TIM								
	CPFR	13%	15%	29%	-1%	1%	14%	17%	12%
Supplier	TIM								
	CPFR	20%	23%	17%	-4%	0%	22%	21%	26%

Impact on Order-Fill Rates (d)

Figure 3 indicates an output of the simulation model that allows the comparison of the average inventory trajectories over time with TIM and CPFR policies in an environment with seasonal demand. As seen in the figure inventory declined over all echelons, especially upstream, in the supply chain, validating that communication and consensus among supply chain members help to mitigate the bullwhip effect.

Figure 4 emphasizes the large impact of collaboration in terms of improved sales and profitability, among all supply chain members in demand environments with predictable "ramp" and "seasonal" demand patterns, respectively. Out of stock situations were reduced as a result of collaboration that in turn enhanced the sales growth. Collaboration also resulted in lower inventories and inventory related costs of capital, space and labor. The reduction in costs and increase in sales enhanced the profitability of the supply chain.

The model also reveals that customer service is improved through CPFR. Improved visibility of the supply chain due to real time sharing of demand information among supply chain partners increased the reliability of supplies, which in turn improved the product availability. Figure 5 illustrates the effect of CPFR on the order fill rates in a "ramp" demand environment.
<<Insert Figure 5 About Here>>
Lost sales were reduced due to better forecast accuracy and faster information flow. Access to real-time data, such as point of sale information, make tasks of replenishment planning easier and more reliable. Hence, order fill rates were improved under a CPFR policy.

5. Conclusions

Although the positive impact of collaboration on supply chain performance has been reported in the literature, this is the first study that investigates the impact of collaboration initiatives on the performance of a supply chain subject to a variety of demand patterns in a realistic context. Most of the studies presented in the literature are limited to two echelons; further, using a simulation approach enabled the inclusion of complex system interactions in the model. This study is important since managers report that they lack the means to assess the benefits of CPFR in their own settings (Aviv, 2002). The results of this study indicate that collaboration significantly improves the performance of a supply chain. Through collaboration service levels, profitability and sales are increased, with lower levels of inventory. In general, upstream members of the supply chain (distributors and suppliers) gain more from the collaboration process, than retailers. In light of these simulation studies, it is also recommended that industry groups categorize their products based on demand patterns and emphasize collaboration initiatives, such as CPFR, along the supply chain of those products that have predictable demand patterns, such as "seasonal" and "ramp" demand patterns, where the effects of these initiatives are most significant. Collaboration initiatives yield less desirable results in environments that have highly random (unpredictable) demand variability, it is necessary, therefore, to define approaches to improve the predictability of demand in such circumstances.

6. Future research directions

A more formal and in-depth statistical analysis is planned for future research. This would include evaluating the effects of collaboration on different demand patterns infused with several degrees of randomness and variability. The results of this research would give useful insights on when systems such as CPFR are essential and beneficial.

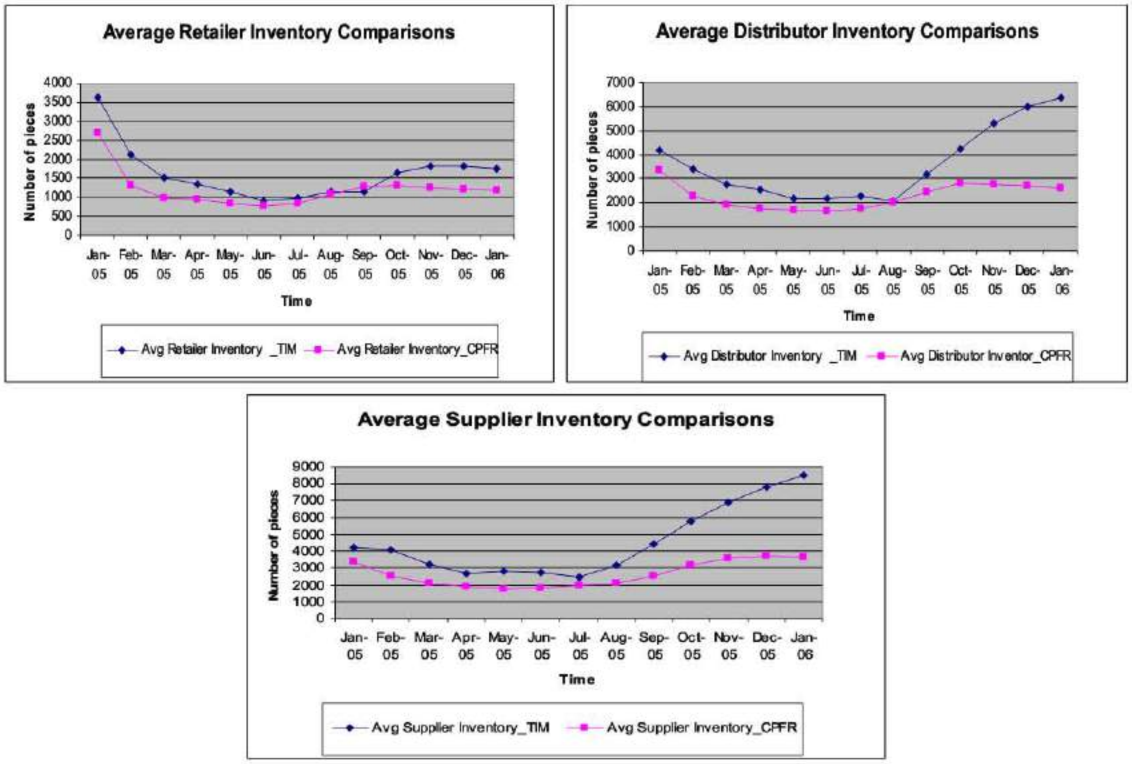


Figure 3: Average Inventory Comparisons (TIM vs. CPFR) under Seasonal Demand

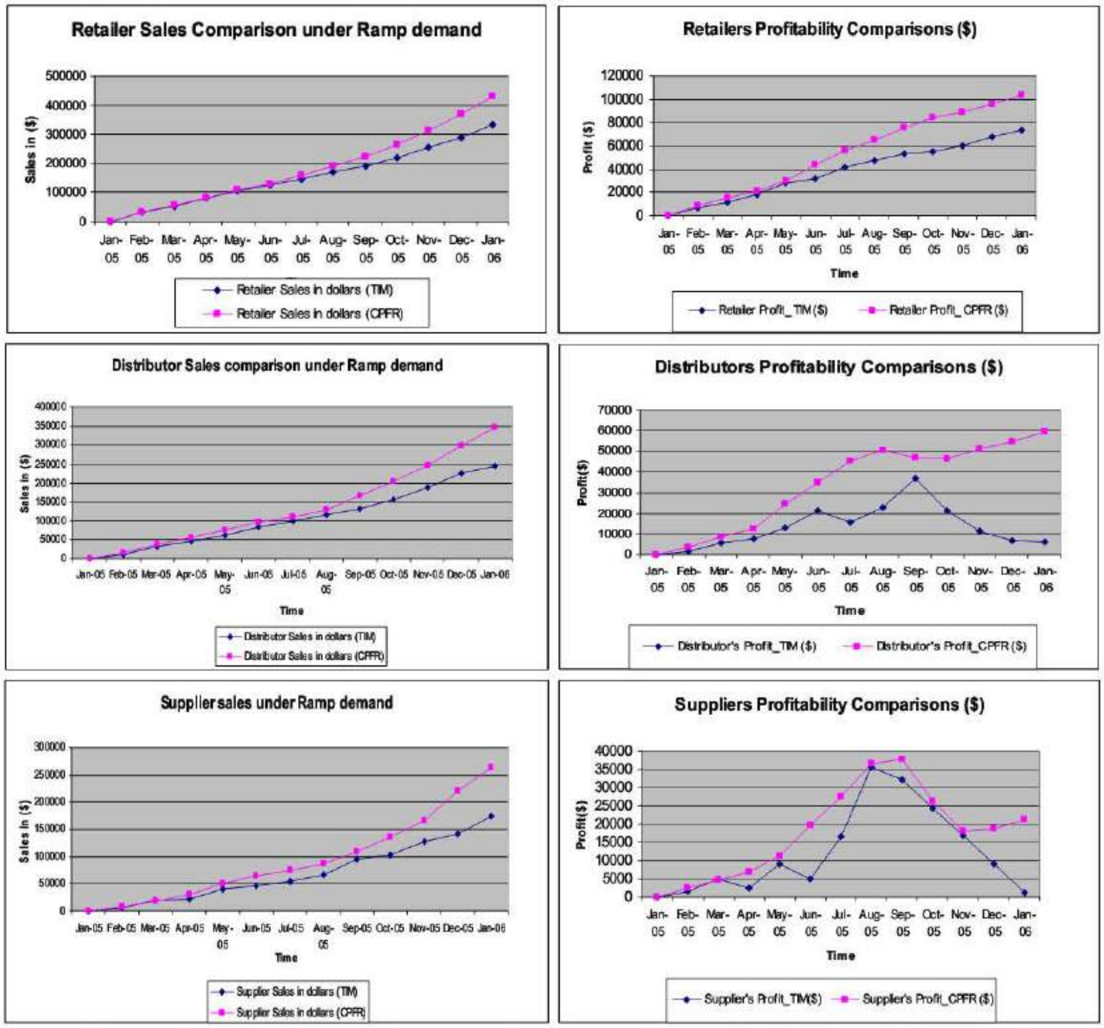


Figure 4: Sales Comparisons under Ramp Demand (TIM vs CPFR) and Profitability ($) Comparisons under Seasonal Demand (TIM vs CPFR)

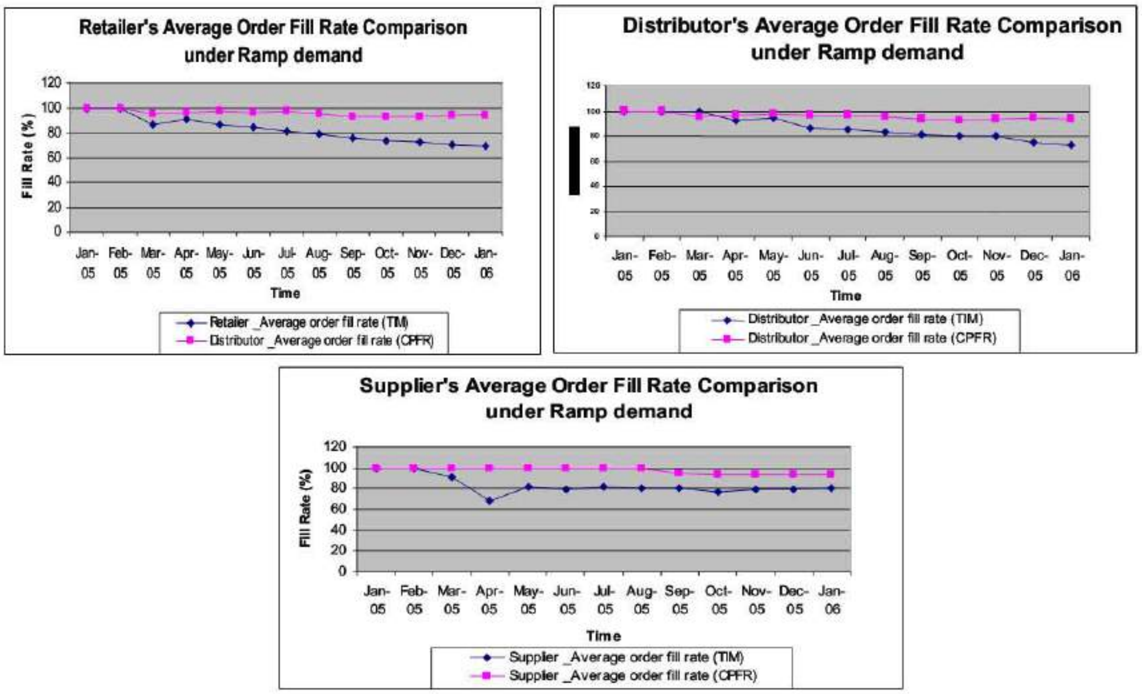
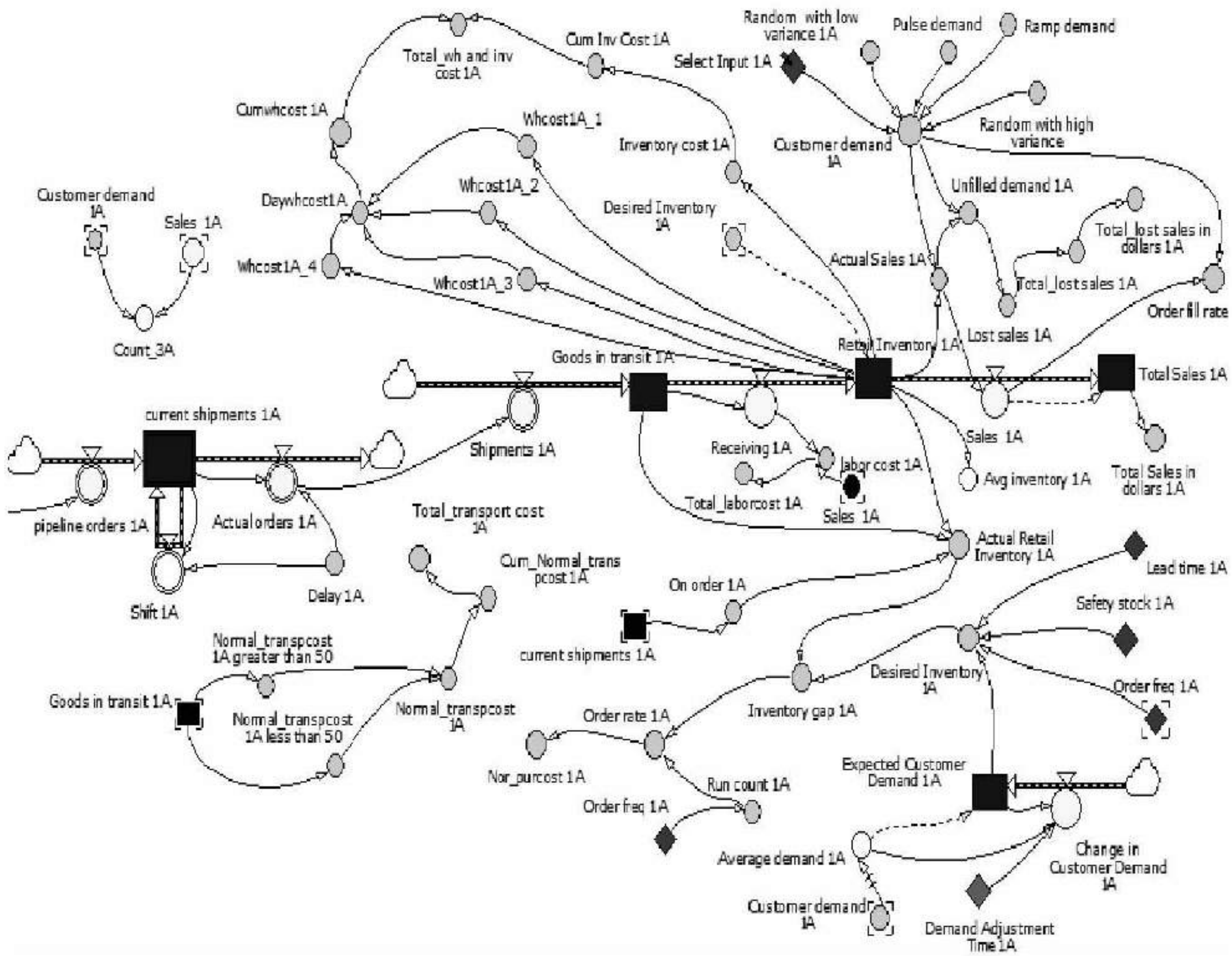
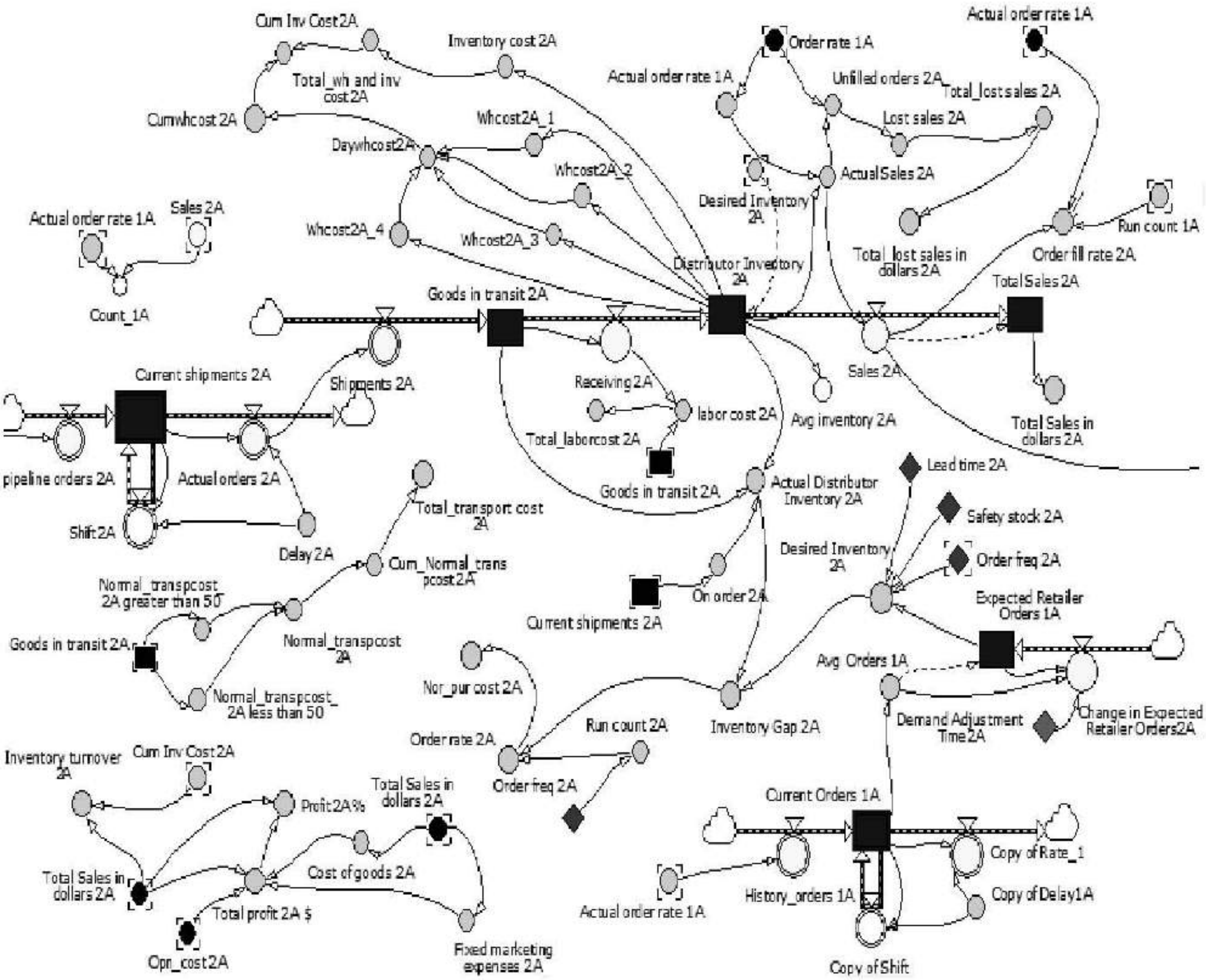


Figure 5: Average Fill Rate Comparisons under Ramp Demand (TIM vs CPFR)

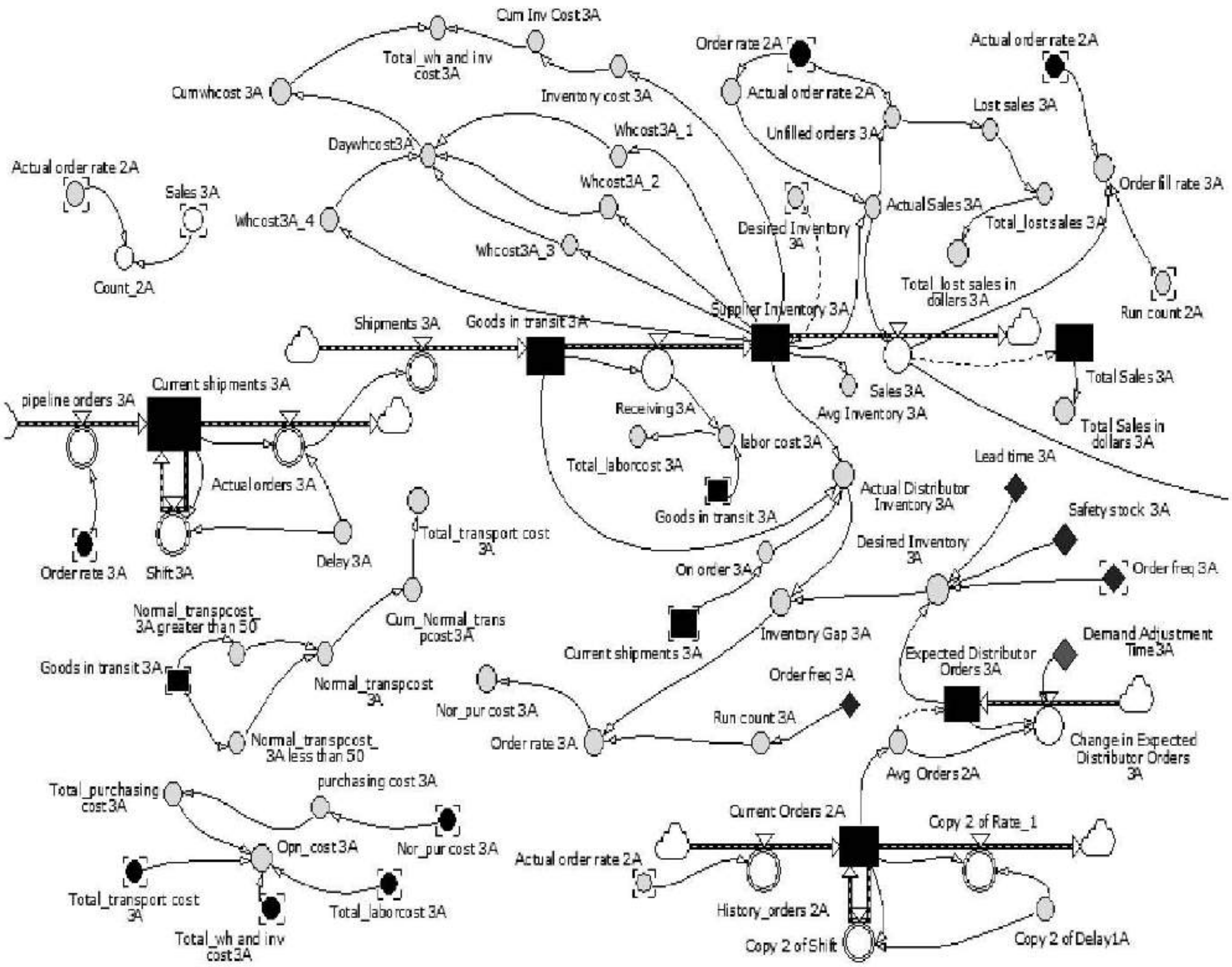
Appendix 1 A – Retailer Sector



Appendix 1 B – Distributor Sector



Appendix 1 C – Supplier Sector



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I/T Infrastructure for a Data-driven Website A Service-learning Project

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Abstract

This paper explores the role of technology in teaching project management concepts. Its focus is on the technology infrastructure to support a data-driven website, and the use of project management software to schedule and track development and implementation. The assignment was initiated as a service-learning consulting project for Computer & Information Technology students in a senior-level project management course. The goal was to learn about project management by implementing a real project. Technology skills acquired by students throughout their academic careers were used to develop the project solution and gain experience in project management.

The paper describes the project and the client profile, reviews the benefits of a data-driven website, looks at the technologies employed to implement the solution, and describes the results of these efforts. The challenges of incorporating a real consulting project into the constraints of a 16-week course are investigated, and the role of project management software is described.

1. Introduction

Service-learning is a method of teaching and learning that combines academic curriculum with meaningful service. It enriches the education process by engaging students in service to their communities. Students apply academic skills to solve real-world problems, linking established learning objectives with genuine needs. They apply critical thinking and problem-solving skills they have mastered to the concerns of the broader community. As Senator John Glen puts it, "Service-learning is education in action."[1]

Service-learning is not something new for Purdue University. Engineering Projects in Community Service (EPICS®) - http://epics.ecn.purdue.edu was initiated at Purdue University in 1995. EPICS® engages engineering students in long-term team projects that address technology-based problems for local community service organizations.[2] However, this study is about the first time service-learning was used for the senior-level Project Management course (in the Computer & Information Technology (CIT) curriculum) at the Purdue University North Central campus. It illustrates how service-learning enhanced the learning experience for this class.

Why use service-learning?

Service-learning provides a number of benefits over traditional classroom educational processes, as shown in Table 1 below.

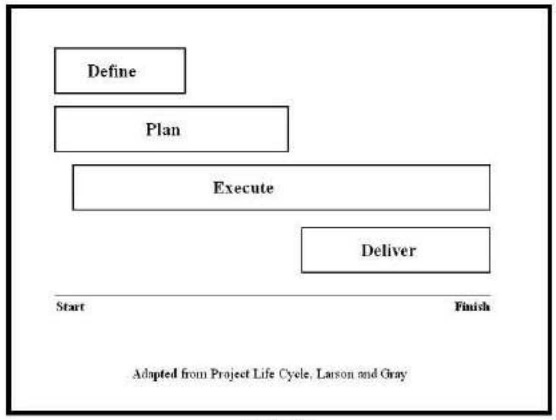
All of these advantages don't come without cost though. The most noteworthy disadvantage to the service-learning approach is the time investment for the instructor and students. This pedagogy requires significantly more time to prepare, teach and learn than standard classroom approaches. The project involved in this study increased the time investment for the instructor by a factor of 3 over the typical upper-level course. Students also indicated that they were spending significantly more time on this class than any of their other courses during that semester. The key to success in overcoming this involved motivating the students (and instructor) throughout the process. By closely working with the client team, the students easily realized the impact this project was going to have on their organization. The value of this made everyone true stakeholders in the outcome, and eager to do what was required to see it to completion.

Table 1. Benefits of service-learning[3]

For Students
▪ Enriches student learning of course material by bringing "books to life and life to books".
▪ Engages students in active learning that demonstrates the relevance and importance of their academic work.
▪ Increases awareness of current societal issues related to academic areas of interest.
▪ Enhances critical thinking and problem solving skills.
▪ Improves interpersonal skills.
▪ Develops civic responsibility through active community involvement.
For the Faculty Members and Institution
▪ Enriches and enlivens teaching and learning.
▪ Builds reciprocal partnerships with the local community.
▪ Creates new areas for research and scholarships, and increases opportunities for professional recognition and reward.
▪ Extends campus resources into the community and reinforces the value of the scholarship of engagement.
For the Community
▪ Provides substantial human resources to meet needs of local communities.
▪ Fosters an ethic of service and civic participation in students.
▪ Creates potential for additional partnerships with the campus.

2. Project management course

The CIT Project Management course introduces students to the knowledge, skills, tools, and techniques that project managers use to plan and manage information technology projects. It begins the process by studying how businesses prioritize projects, their relationship to the strategic plan, and how the culture of the organization impacts the project approach. Special emphasis is placed on the project life cycle (shown in Figure 1), and learning the concepts involved in managing the project phases.



Error!
Figure 1. Project life cycle[4]

This includes the importance of clearly defining the scope, the trade-off between scope, time, and budget in managing the quality of a project, and managing risk, expectations, people, and communications. The procurement process and externally provided services are also explored. The conceptual material is covered in the early part of the course, followed by hands-on assignments to reinforce these concepts.

3. Techniques & software

Concepts and practical approaches to technology project management are explored through traditional classroom delivery methods. These include lectures, readings, and exercises from textbooks and ancillary materials. The students are also introduced to technology tools to reinforce these conceptual ideas, which include Microsoft Project® software, and in the past, SimProject®.[5] SimProject® is a web-based project management model that provides a simulated experience in managing a project. Students gain experience as a project manager as they acquire and manage resources through multiple scenarios, and competitive and collaborative project team activities.

4. Simulations vs. real projects

Although SimProject® has many features to simulate calculated and random situations that occur when executing IT projects, it lacks the learning level that occurs when students are immersed in an authentic real-world situation. The collaborative element in the simulation helps students work as teams through the project planning phase, but as the execution process begins, students start to look at the simulation as a game. SimProject®'s competitive element pits teams against one another, resulting in team rankings at the end of each project phase cycle. Lower-ranked teams begin to focus on rank rather than project goals. This focus results in strategies geared toward SimProject®'s scoring system rather than to the successful completion of the project.

A service-learning project provides all of the elements of a real-world project, because that is exactly what it is. To successfully implement an IT service-learning project, students must possess technology skills for the solution and the instructor must have the experience to know how much can be accomplished in the course of the semester. When a balance of these requirements comes together, no simulation can match the learning achievement or feeling of satisfaction gained by successfully implementing a real project solution.

5. The project profile

The client for this particular project was an all-inclusive parochial school, with about 170 students in grades Preschool through Eight. Although the school is of Catholic denomination, the student body consists of about 1/3 non-Catholic children, and includes a rich diversity of faiths and cultures. The funding for this non-profit school is provided by student tuition, a myriad of fund-raising events, and a subsidy from its local church. Each grade has its own classroom and teacher, however all extra-curricular activities including sports programs, music, fine arts, and technology education are provided by parent volunteers.

The school had a website that was developed and maintained by the spouse of one of the teachers, as no faculty or staff members had sufficient technology skills to do it. This person had to relinquish the task of maintaining the website in 2002 due to illness, and the website was essentially left in this state until the instructor of the project management class was called in to look at it in 2007.

The site was developed using the Adobe Dreamweaver® product. All content was built into each webpage, requiring someone with Dreamweaver® skills to make changes to the information. Even if someone with the required skills was found, all of the responsibility for maintenance to the site would fall on that one person, a situation that is tough to maintain in the long run using volunteers.

6. Project scope

Once the decision was made to develop a new web site for the client, it became clear that the scope of the project would have to be closely managed in order to deliver a solution within the constraints of a 16-week course. The first five weeks of the course were spent studying project management concepts to prepare the students for their roles as co-project managers. In the sixth week of the course, the class was introduced to the school principal, business manager, and some of the teachers, to gather requirements for the project and begin the planning and design phases of the task.

7. Deliverables

From these meetings, project deliverables were developed, which included pages for a variety of topic areas, plus documentation and training:

- Home page
- About page
- Resource page
- Faculty pages

- Classroom pages
- Special Event pages
- Athletic pages
- Various Calendars

A data-driven approach was chosen for the solution, to separate the technical programming from the information content. This would allow teachers and staff to personally keep their respective pages updated, without need of technical know-how. This very user-friendly approach was great for the client, but much more difficult to implement by the project team.

8. Constraints

The primary constraint of the project was time, as the end of the semester was an absolute deadline that had to be met. This left cost (the amount of time students could be expected to work on the project) and scope as the crucial elements to be managed throughout the project management process. The scope evolved somewhat as the solution was developed, but the data-driven approach was never abandoned as it was deemed an essential requirement for a successful implementation.

9. Risks

The major risk in the project was that when the end of the semester arrived, the project team would disband and nothing more would be done on the website. This could result in the delivery of a website of such poor quality that it would share the fate of the site it was replacing or worse yet, nothing at all. Neither choice would reflect well on the reputation of the university. This risk was managed by closely tracking progress, and ultimately, putting additional resources on the project. The additional resources were obtained by "putting in overtime", and every student in the class participated. This level of commitment to the project was motivated by the ensuing teamwork and the shared common goal to delivery a high-quality product.

10. The project solution approach

Websites are developed using html (hyper text markup language) to create web pages and http (hyper text transfer protocol) to communicate between a client browser and a web server. Web pages come in two primary forms: static web pages and dynamic web pages. Static web pages are retrieved by the server and delivered intact to the client. Dynamic web pages are retrieved by the server but modified as they are delivered to the client. They may be modified on the client-side, which basically changes the look of the page, or on the server-side, which can change the content of the page.

The client's original website was constructed using static web pages. That is, the information content was built into the page. In order to change the content, the web page had to be changed and the page reloaded to the web server. Updates to a static web environment are typically handled by someone familiar with a particular web-building software product. All changes go through this single web expert, making that position a very busy one, if the website is to be kept current.

11. Data-driven website

Data-driven websites are dynamic, that is, the content is kept separate from the web page, in a database where it is joined with the page based on the context of the request. To change the content, an update is simply made to the database. No change to the web page is required. Anyone, regardless of their technical expertise, can update the content of a page as long as they have the authority to do it. This authority is controlled by assigned user IDs and passwords. Each page is maintained by the person responsible for its content, greatly easing the web maintenance effort by spreading it around.

There is more up-front work in a data-driven website because web pages must be created that can update the database. However, the requirement for a data-driven website was imperative for the client, as there was little technology experience available within the organization.

12. Technology infrastructure

There are a number of choices available for the software infrastructure to support dynamic, data-driven websites. These fall into two general categories, Open Source products or proprietary Microsoft products. Open Source products include the LAMP infrastructure – Linux®, Apache® Server, MySQL® database, and PHP® programming scripts. Microsoft products include those listed below, which were used for this project based on the software available from the client's web hosting supplier and the predominant skills of the students. The infrastructure products used were:

- Internet Information Services (IIS®) – internet-based services for web servers using Microsoft Windows®
- ASP.net® – a web application framework for building dynamic web sites. A component of Microsoft's .Net® platform, it can be used with any .Net® programming language.
- VB.Net® – Microsoft's Visual Basic programming language for the .Net® Framework
- SQLServer® – Microsoft's relational database management system
- Google™ Calendar – a web-based calendar system that easily integrates with user websites

All of these products (with the exception of Google™ Calendar) are contained in Microsoft's Visual Studio.Net® integrated development environment, available on workstations at the university and for students' personal computer systems, for a nominal fee. This allowed the website components to be developed on individual workstations, with each student working on the pages for which they were responsible.

In addition to this, students were able to run a copy of the Microsoft Project® software to track and manage the progress of the project. Each student was responsible for the work breakdown structure and time estimates for their piece of the solution.

13. Project roles

The students performed the roles of consultants in this project, each responsible for managing their portion of the definition, planning, execution, and delivery of the project solution. As project managers, they contributed to the selection of the software architecture, negotiated their roles in implementing the website, established the initial schedule, and made resource and scheduling adjustments as the project progressed. They handled communications with the client to gather system requirements and deliver training and documentation.

The instructor of the class performed the role of overall project manager, establishing general guidelines for the project process, establishing the initial interface between the client and consultants, and providing guidance as required.

Working directly with the client, students soon learned that they had to resolve conflicting input as they developed system requirements. Also, initial task times for developing website pages were exceeded almost immediately after the project got underway, as the learning curve for the development infrastructure products was somewhat under-estimated. When these times were corrected in the project schedule, it became clear that the project would not be completed by the required date. Resource adjustments were made, that included redirecting some consultant skills and scheduling overtime, which put the project back on track.

14. Demonstration

The project was completed by the end of the semester in which it was scheduled, although implementation occurred during final exam week instead of the last week of classes. For a demonstration of the result, the site can be accessed at: http://stmaryofthelakeschool.com/.

The following screen snapshots show how the same web page view differs depending on whether someone is just browsing the page or an authorized user is in update mode.

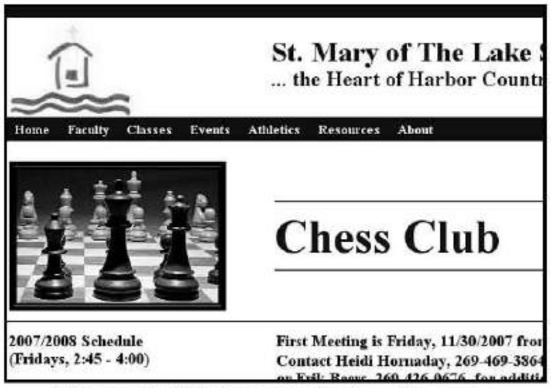


Figure 2. Webpage during browse

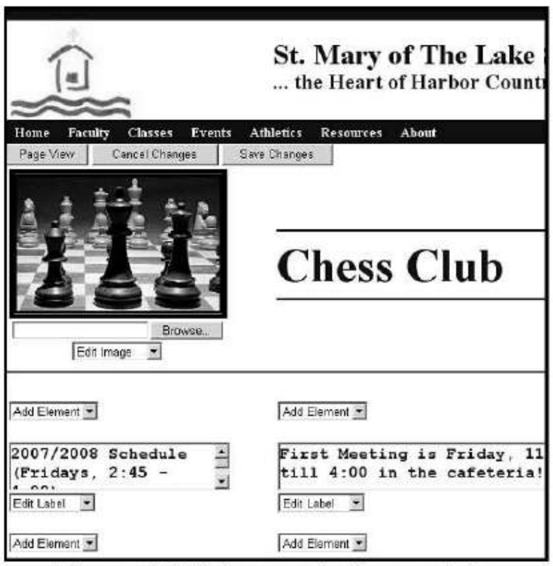


Figure 3. Webpage during update

15. Stakeholder feedback

The client has been extremely pleased with the results. Most teachers have populated the database with content for their personal pages and some are actively using their classroom pages. The administrative staff has loaded calendars, special events and general school information. Everyone has been impressed with the ease of maintaining the website. The principal has commented that it has far-exceeded her expectations, and is working to get all teachers to load and maintain their respective pages.

Student feedback on the project was excellent as well. As expected, there were issues almost immediately once work began on the project. The database design went through several iterations before it reached its final form, and since it was on the critical path, the schedule was negatively impacted. Students worked as a cohesive team, making adjustments and helping each other to recover the completion date. There seemed to be a genuine sense of pride, well deserved, in the product that resulted.

16. Conclusions

Overall, it was a very worthwhile project. Students learned more and put into practice the project management skills they acquired. It was for a good cause, students received a much better insight into what it takes to manage a project, and the instructor can feel good about putting it all together. Further research on how to put this approach into a two-semester course series is being studied.

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The Rise and Fall of Commerce One Inc.: Lessons Learned

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Abstract

Commerce One Inc. (Commerce One), once a bellwether in the e-commerce field before the burst of the dot-com bubble, developed software systems enabling companies to transform their purchasing interactions into real-time trading networks. Commerce One acquired the e-business budgets of many Fortune 1000 companies. It facilitated the computerization of various work functions including supply chain, payment, and procurement across all industries from automotive to health-care. On December 28, 1999, as a highflier in the dot-com era, Commerce One sharply increased to $1,655 (a split-adjusted) per share. In the universe of corporations, Commerce One was a bright meteor. Today, Commerce One no longer exists. The short but undulating history of e-commerce witnessed the company's rising and falling, from its position as an industry leader to another file in bankruptcy court. "How come?" One may wonder. This paper will examine the internal and external events that took place around Commerce One, exploring the industry backdrop, the key events in the company's history, the challenges that ultimately overcame it, above all allowing us to draw lessons from its tragedy and be wiser in the future.

1. Introduction

Commerce One started in 1994 as DistriVision Development Corporation. In 1997, the company changed its name to Commerce One. In 1999, the company went public. Supporting processes and transactions, Commerce One created superior online buyer/supplier relationships through the Internet. Being a part of a global e-commerce trading network, Commerce One had been on top of delivering advanced technologies. It brought worldwide diverse firms together to conduct e-commerce on a competent business platform. It also developed libraries and languages that helped to shape many of the concepts behind XML (*Extensible Markup Language*) and SOAP (*Simple Object Access Protocol*) [13]. Over the years, this organization helped companies adapt their IT assets to business opportunities with new functionality and flexibility in their practices and became a leading provider of well-developed software assisting in the collaboration of businesses with their partners, customers and suppliers. Commerce One's business services ranged from IT to logistics and management.

Commerce One made it possible for over 600 companies to work together with their customers, suppliers and partners, including Citicorp, Boeing, Shell, Eastman Chemical, Telecom... Commerce One's strategic partnerships integrated GM, Chrysler, Mitsubishi, Pentellus, and Columbia/HCA Healthcare Corp. The workforce of Commerce One at its height, globally, included over 3,800 employees [10].

In its peak years (1999-2001), Commerce One swiftly married with many key companies in the industry. In December 1997, Commerce One formed a strategic relationship with SAP. In 1999 Commerce One expanded rapidly as it became General Motor's online marketplace. On Sept. 26, 2000 Microsoft Corp. and Commerce One announced they were expanding and elevating their longstanding strategic relationship. To collaborate on delivery of the industry's next generation of B2B e-commerce solutions worldwide, Commerce

One and Microsoft would align a global go-to-market strategy to drive the growth of e-marketplace adoption. In October 2001, Intel and Commerce One signed a three-year alliance involving joint marketing and engineering. Commerce One and Intel were preparing a hosted version of Commerce One's marketplace software.

The Internet hype, advanced technology and potential cash had led to approximately 6,000 startups [9]. However, only a few still remain prosperous. For the others, thousands of jobs have been lost and several hope to emerge strong again. The real goal all along for e-business since the 1990s had been to streamline commerce. Issues like changing business environments, complex requirements and new international laws negatively affected e-commerce. There are numerous opinions of what went wrong, but it is evident that lessons could be obtained from Commerce One's and other Internet-based firms' downfall.

Rovenpor's study [5] on the collapse of dot.com companies showed that it was the result of a variety of factors. Too many dot.coms placed emphasis on brand building and advertising; managers did not realize the importance of establishing financial controls. Getting a head start proved beneficial for eBay and Yahoo, but the study was indifferent as far as size and youth of the dot.com firm as a factor. On the other hand, inadequate strategic planning and deficient management characteristics did have a major impact on future corporate success. Additionally, the value of products was typically pushed aside in favor of more discounts to attract customers. In the long run, the idea of increasing revenues was often forgotten. For some dot.coms, managers did not have the experience or education to run a firm in such a fast-paced and dynamic environment.

Outside factors also played a key role in examining dot.com failures. One factor was resource scarcity. Obtaining funding can be extremely hard for companies that were on the verge of bankruptcy. Another factor, as in any industry, was competition from other companies offering similar and cheaper products and services. Similar to many dot.coms, they had chosen to compete on the basis of *convenience* and *price* when customers still wanted *functionality* and *reliability*. A combination of various reasons accounted for the struggle for corporate survival. However, it is apparent that further research could be conducted, particularly in the same industry.

The Boston Consulting Group [2] studied various enterprise ideas like resource planning, e-commerce and supply chain management. Commerce One was one of the companies examined in this analysis. The study had revealed vendor dissatisfaction with little value and a high cost, timeliness was not paramount, options were overlooked and return on investment was diminishing. The basic result showed that companies should pursue initiatives only after doing the critical up-front analysis and strategic thinking that makes positive outcomes much more likely.

Nonetheless, Commerce One struggled to be a survivor for a while, further enhancing programs and increasing its services. It produced genuine products for hundreds of customers, but it had become difficult for Commerce One to get new customers. Liedtke [6] indicated that since 1994 Commerce One had lost $3.7 billion with series and mass layoffs of over 3000 jobs in the past four years trying to survive.

2. What went wrong?

During the late 90's Commerce One was one of the elite companies. The Commerce One model was to act as a complement to existing ERP systems by providing companies' automation of their procurement procedures. This allowed for greater control, access to the right suppliers and deals that included volume discounts. Commerce One had distinguished itself as the leading software provider of robust applications in market of procurement and auctions. The company was generating revenues at a pace that no one ever thought was possible. Its rise was not only a mania. Looking at the growth of the company and the long list of its customers, one might ask how it is possible that Commerce One went out of business. So what did go wrong?

At the peak time of e-procurement frenzy a few years ago, two companies dominated the B2B space: Commerce One and Ariba. Despite Commerce One and Ariba were both key players in the exchange market, they were perceived different. With the near-collapse of the original B2B model, both companies sought new niches. Commerce One was moving towards web services in an attempt to find a viable market. Ariba, meanwhile, emphasized enterprise spending management [11]. Ariba strongly believed that a software firm's role is to be a tool provider. As the B2B world divided into industry sponsored exchanges and independent marketplaces, Ariba avoided involvement in managing its customers' exchanges. Conversely, Commerce One believed that software makers had to do more than simply provide tools. They had formed strategic partnerships with its customers and helped manage their online marketplaces [1]. Ariba has been a successful company even today [3].

The management team tried to blame the loss of income on the economy. During a press conference, Mark Hoffman, the ex-CEO said, "The generally challenging macro-economic conditions are impacting our business primarily by delaying IT purchases and lengthening sales cycles". The paradox is that while Commerce One relied on lightning-fast operations, it responded sluggishly to the crash [12].

One of the missteps that B2B companies made prior to the crash was over zealous consolidation for the sake of keeping up with competition. In addition, inadequate management, lack of a workable business model, excessively complicated data and software integrations, and the concurrent crash of the NASDAQ and NYSE stock exchanges were all part of the depressing economy. Also, the terrorist strikes of September 11, 2001 led to a decrease in overall technology spending.

Technically, there were many challenges surrounding the incompatibility of two competing standards – EDI and XML. This led to project delays and declining customer satisfaction. The acquisition frenzy led to B2B companies racing to acquire smaller companies before their competitors, which forced the B2B companies into the red. Although the potential for market demand of B2B companies existed, there was an uncertain market for online exchanges.

Additionally, let's explore the internal (*strategic stagger, operational chaos, technical problems)* and external factors (*unfriendly environment, unanticipated episode, unexpected event)* that affected the company's financial performance.

3. Internal factors

3.1. Strategic stagger

The correct strategic plan for a small company should be profitability early on and then become acquired, hopefully, by a "white knight". The initial success of Commerce One, along with the available cash on-hand, clouded management's judgment and resulted in a missed opportunity that could have kept the company successful.

Commerce One did not seem to have direction. Many analysts and prospective customers criticized Commerce One for becoming involved in too many markets. It started as an e-marketplace solutions company to offer customers ease of trading over the Internet. Shortly after that, Commerce One released 5.0 Suite to provide solutions in e-procurement and e-sourcing. In the matter of months, Commerce One moved into e-collaboration and introduced the improved 6.0 Suite enabling Web solutions. Furthermore, Conductor, an application platform with integration components was introduced in March of 2003. Many critics believed that not having a focus caused Commerce One lose its credibility. Many customers were leaving Commerce One and looking for alternative solutions.

Instead of research & development, Commerce One placed its resources in sales and marketing for its products. The result was the absence of sound business strategy. This lead to a poor business model with the absence of declared business benefits (namely long term profits). Commerce One was so eager for sales, they had forgotten the need to re-invest in the product. This was based upon a business model to "sell it first, fix it later". The company was obsessed with advertising and expanding. Commerce One tried to constantly compete with companies such as Ariba and i2. As a result, they spent much time and money on advertising. The financial side of the business was overlooked. Even though the company was able to generate sales, it still reported a loss on its income statement quarterly. The company never reached profitability and had changed business models several times since going public in 1999.

3.2. Operational chaos

Commerce One managers were short-sighted, careless and overambitious with much cash on hand. The management of the company, especially its former CEO and Chairman Mark Hoffman, did not perform a thorough market research. Hoffman acknowledged waiting too long to obtain the strategic partner that Commerce One needed. Commerce One failed to realize that its software was not adopted at the same rate as it was being released. Companies required more time to make multimillion dollar decisions. Commerce One was manufacturing software one after the other. Because of its popularity of early e-marketplace software, Commerce One eventually lost many potential customers since the new software was not accepted by companies.

The firm's offices were in the most expensive commercial real estate areas of Silicon Valley. Even after its stock price and earnings went into a free fall the company remained in these locations. Commerce One remained dormant with its faulty outdated software products and with its staff reductions. While other firms in the industry such as Oracle, SAP, and Ariba were adjusting their product offerings and reducing their staff by 20-40%.

Too much emphasis was placed on joint ventures and alliances. In the first quarter of 2002 Commerce One reported only $31.8 million in revenues, representing a quarter-over-quarter decline of nearly $25 million. "According to Commerce One CFO Peter Pervere, the substantial majority of license revenues derived from royalties from Commerce One partner SAP on joint sales of co-developed projects" [4]. No company should rely on a small number of partners for its revenues. Such dependency would put Commerce One in jeopardy.

Commerce One's leadership team was in chaos. Hoffman continuously insisted on making a mark in the industry while other executive team members were more hesitant. Hoffman was quoted in a staff meeting as saying "either you believe in the strategy or leave the company" [10].

3.3. Technical problems

In order to keep up with the growth in the industry, Commerce One began to compromise on quality. Preliminary testing of its software was inadequate before it was shipped to customers. As a result, engineers had to be ready to fly anywhere to install programs to create a positive atmosphere for additional sales. Commerce One found out the hard way when it lost customers due to the declining quality. The result was faulty software and resentful customers. Unsatisfied customers lead to loss in sales, which in return led to loss of revenue. This also led to tension between engineers and the sales team. Internal conflict began adding frustration to an already difficult situation, as sales began to dwindle.

Communication and data exchange among businesses with different proprietary technology/computing system was more difficult than expected. Organizations offering e-procurement products had a difficult time adjusting their suppliers IT capabilities to comply with their format and software requirements. Moreover, due to organizational structure limitations they relied on third parties to provide integration services, which affected the implementation process. Therefore, organizations did not perceive any improvement in cost management. Consequently, tech companies focused on developing micro/enterprise applications where organizations were productive from some Internet benefits. However, they went back to pre-exchange style dealing with suppliers on a one-to-one relationship.

4. External factors

4.1. Unfriendly environment

At the beginning, B2B marketplace offered organizations the possibility of obtaining savings by purchasing repetitive and low-value goods online. This concept would show the benefits of an idealistic competitive market. There would be a perfect flow of information and price of the product along with interaction between supply and demand. E-marketplace software vendors asserted that by moving the purchasing function over the Internet would improve the process. This idea was initially widely accepted and Commerce One was one of successful start-ups businesses.

In spite of Commerce One and their partners' efforts for building an e-marketplace with financial benefits to their customers, enterprises were reluctant to switch their business process over the Internet. Furthermore, suppliers were concerned their benefits would decrease significantly. They feared that a market with symmetric information might destroy their profitability. Even though the company worked together with recognized allies, Commerce One was not considered as solid business and, it was even perceived as an unwieldy and disappointing endeavor to push customers to use Microsoft' products.

The decline in capital spending on computer software used in e-commerce exchanges caused tech companies to look for other growth opportunities. Moreover, efforts of these organizations to promote the utilization of B2B e-commerce solutions failed. The trend of shifting from mega marketplace to enterprise application was noticeable in 2001. The burst of dot.com businesses caused Commerce One to lose customers.

4.2. Unanticipated episode

In December 1997, Commerce One formed a strategic relationship with SAP. Afterwards, they joined to develop MarketSet and Enterprise Buyer procurement applications in 2000. Commerce One was doing well and waited until August 2001 to explore a merger with SAP. By that time, it was too late. A faster response could well have prevented Commerce One from falling. In 2002, SAP announced it would end license agreement with Commerce One. Therefore, Commerce One lost an important source of intellectual property and capital investment. Commerce One's license revenues were \$79.1 million in 2001, \$26.1 million in 2002, and only \$0.4 million in 2003 when the partnership was ended.

Many analysts were shocked with SAP's announcement of breaking alliance with Commerce One. SAP moved on to develop its own similar software. Such action put SAP in direct competition with Commerce One. That caused Commerce One's stock drop to half of its value right after announcement. Many analysts criticized SAP for not treating small companies fairly. There were few cases when SAP, after acquiring needed technology, would break the alliances with a smaller or less influential company.

4.3. Unexpected events

The terrorist attacks of September 11, 2001 directly led to a "decline from 4.3 million pageviews in August to 2.1 million in September" [7]. Mergers and acquisitions were also affected from this event, as activity declined 33.2% from 48 in 2001 to 32 deals in 2002. Mergers for the first half of 2003 were also down 37.1%, although this was also affected by the onset of the war in Iraq [8].

After the September 11 attacks, Commerce One's value was plummeting by the week, which shrouded the industry in gloom. It turns out that Hoffman's organization, like many of its rivals, was not only engineered for a boom, but the entire business strategy was molded by the successful dot-com times. Hoffman remained optimistic in 2001, even as his industry plummeted. Unlike many rivals, which slashed its staff and offerings early in the year, Hoffman maintained 3,000 employees through much of 2001 eager for a bright future that never arrived.

5. Conclusion

Commerce One went from over a $20 billion market cap to bankruptcy in a couple of years. Thousands of employees and investors had lost a big fortune from its downfall. Hoffman's belief in a remarkable turnaround simply never happened. Nevertheless, strategic errors, disappointing mergers, and overspending pushed Commerce One to the point of being unable to recover.

The benefit of hindsight, Commerce One and Ariba had attacked the market with slightly different (and shifting) strategies yet, like most Internet startups, both had accumulated large deficits and offered only the promise of future profits. Actually, Ariba has adjusted itself to the environment better. It briefly entered into e-marketplaces, observed there was not the revenue it needed, and refocused as a software company.

We will never forget the time when Commerce One was one of the Internet's highest fliers, with a market cap of $21.5 billion at its zenith. Commerce One was indicative of a lost generation of tech companies created in the past decade. A bright meteor's rise and fall in the universe of corporations has taught us a big lesson.

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Ruggedness Evaluation of the Open-Hole Test Procedure

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Abstract

This paper represents a study aimed at evaluating the ruggedness of the open-hole tensile test procedure used to characterize the mechanical properties of composite laminates. A Plackett-Burman design with 12 runs was initially utilized to identify factors that are likely to affect the peak load measurements. Levels of the factors considered were controlled within the ranges specified by ASTM D5766 and related standards. The results indicated that the average peak load was sensitive to changes in the test speed and width of the test specimen. The study concluded with recommended limits for controlling these two factors to assure consistent test results.

1. Introduction

Composite materials are macroscopic combinations of two or more distinct materials, having a discrete and recognizable interface separating them [1]. Composites are used not only for their structural properties, but also for their electrical, thermal, tribological, and environmental properties. Modern composite materials are usually selected to achieve a particular balance of properties for a given application. To make sure that the material has the required properties they are tested using a number of destructive and non-destructive testing techniques. Complete coverage of the various test methods may be found in [2-4]. One of the important tests used to determine the tensile properties of composite laminates is the open-hole tensile test. Standards set by the American Society for Testing and Materials (ASTM) provide the procedure for conducting this test. The objective of this research is to evaluate the ruggedness of this test procedure as performed at the fatigue and fracture laboratory at Wichita State University. This procedure is utilized to qualify mechanical properties of polymer matrix composite laminates for use in the Aircraft industry. An overview of related research and test standards is presented in the following section.

2. Background

It is generally recognized that polymer composites with both discontinuous and continuous fiber reinforcement possess high specific stiffness (i.e. density related) and strength when measured in plane, therefore such composites, are frequently used in automobile, aerospace, marine and energetic applications [3]. With high strength-to-weight ratio, even greater than aluminum and excellent resistance to fatigue, creep, corrosion and wear, modern composite construction offers several advantages over conventional techniques. In aircraft design, composites allow an easy way to achieve a low drag airfoil. Composite airplanes are usually faster for a given horsepower than their counterparts because of airfoil shape and smoothness [5].

The constituent materials of a composite can be categorized into matrix and reinforcement. The matrix material surrounds and supports the reinforcement material by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties [2, 3]. In manufacturing of composites, the objective is to effectively use the overall material properties by method of combination and simultaneously reduce the effect of less desirable properties. The objective of composite testing is to make sure that the composite have the required properties. In order to estimate strength and stiffness, structural materials are subjected to testing [4].

Non-destructive and destructive tests play an important part in determining the properties of composites that are being used in modern day aircrafts. Mistou and Karama [6] noted that tensile testing is the direct way for characterizing the mechanical elastic properties of materials. This method consists of applying regular increasing load on a sample in a uniform manner to determine the tensile, compressive, shear, flexure and fracture properties of a composite. According to the ASTM Standards D 3039/D 3039M [7], a thin flat strip of material having a constant rectangular cross-section is monotonically loaded in tension or compression while recording the resulting strain. The ultimate strength of the material can be determined from the maximum load carried before failure. If the coupon strain is monitored with strain or displacement transducers then the stress-strain response of the material can be determined. Consequently, the ultimate tensile or compressive stress, tensile or compressive modulus, Poisson's ratio, and transition strain can be determined. Common types of tension tests are defined based on the specimen shape. These include un-notched, open-hole, and filled-hole specimens.

With the growing demand for composites, new test methods are being continuously developed and existing techniques are being verified and reexamined. Ruggedness is a term used to describe the sensitivity of a given test procedure to changes in the environmental factors and test conditions. In general, the purpose of a ruggedness test is to determine factors and conditions that influence measurements from the test procedure [8]. A rugged or robust procedure should be insensitive to normal changes in operating conditions. Otherwise, efforts should be made to control these conditions within tighter limits or redesign the test procedure. The next section provides detailed description of a ruggedness test performed at the fatigue and fracture laboratory at Wichita State University.

3. Experimental work

In order to study sensitivity of the open-hole tensile test procedure, statistically designed experiments were performed under varying operating conditions. The test specimens were cut from a single composite panel made of twelve-ply plain weave carbon fiber using milling and grinding operations. The geometry of an open-hole tension test specimen is shown in Figure 1. All the specimens were tested along the 0° fiber direction.

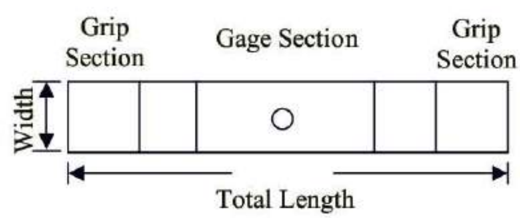

Figure 1: Schematic of open-hole tensile test specimens

The holes are drilled and finished to final diameter using carbide reamers, so as to prevent delamination. A 22-kip servo-hydraulic actuator mounted on a 22 kip MTS load frame was used for loading. The MTS test equipment was calibrated and verified according to the ASTM E4 standard to ensure the accuracy of the load and displacement readings. The actuator was controlled with the MTS Flextest-GT system, and the MTS Testworks software was used to program the parameters for controlling the test and acquiring data. Recorded data included time, actuator displacement and force. To hold specimens on the load frame, special grips were used as shown in Figure 2. Both ambient temperature and relative humidity were noted during the test.

Figure 2: Open-hole tensile test setup

3.1. Choice of factors

The objective of this study is to investigate the effect of changes made within permissible ranges of operating conditions as specified in the standard test procedure. Nine independent factors were identified as controllable and selected for the study. These factors are shown in Table 1 together with their respective levels. Factor levels were selected based on the ranges specified in pertinent ASTM standards.

Table 1: Test factors and their levels

Factors	Low level	High level
(A) Speed of Testing in/min	0.03	0.07
(B) Gripping length (in.)	1.5	2.5
(C) Hole Diameter (in.)	0.247	0.253
(D) Width (in.)	1.45	1.55
(E) Length (in.)	8	12
(F) Grip Pressure (psi)	2000	2500
(G) Temperature (°F)	68	78
(H) Hole Center (in.)	0.004	0.006
(J) Soak Time (min.)	5	10

3.2. Response variable

The open-hole tensile (OHT) test is performed in accordance with test method ASTM D5766 [9]. Similar to test methods D6484 and D6742, the ultimate tensile strength for OHT specimens is determined based on the cross-sectional area of the specimen, disregarding the presence of the hole. The loads versus strain readings (or transducer displacements) are continuously recorded during the test. From the generated data, the maximum load (in pounds) is calculated and used as the response variable.

3.3. Choice of design

Screening designs are often utilized in ruggedness tests with the assumption that most of the control factors (operating conditions) considered have little or no effect on the observed measurements. As pointed out by Montgomery [10] saturated fractional factorials can be used to investigate up to k = (N -1) factors in only N runs. Both geometric and non-geometric arrangements were appropriate candidates for this study. However, a Plackett-Burman design with N = 12 run was selected to screen the nine control factors identified in Section 3.1. It is worth noting here that a geometric two-level fractional factorial would require 16 runs to screen the same number of factors. In addition, a Plackett-Burman design (of resolution III) can be projected into full factorial in any subset of 2 or 3 of the original factors. The design matrix and corresponding values of the observed responses are shown in Table 2. Experimental specimens were prepared and tested in a randomized order. The failure mode for all the specimens tested was lateral gage middle (LGM), meaning that failures occurred at the center of the specimens passing through the holes as shown in Figure 3. This is a desirable failure mode as per the ASTM standard and confirms that all tests were performed in a correct manner.

Figure 3: Specimen with LGM failure

Table 2: Design matrix*

Run	Speed (A)	Grip Length (B)	Hole Dia (C)	Width (D)	Length (E)	Grip Pressure (F)	Temp (G)	Hole Center (H)	Soak Time (J)	Peak Load (Ib)
6	.07	2.50	0.247	1.55	12	2500	68	.004	5	8330
9	.03	2.50	0.253	1.45	12	2500	78	.004	5	8373
4	.07	1.50	0.253	1.55	8	2500	78	.006	5	8350
3	.03	2.50	0.247	1.55	12	2000	78	.006	10	8405
12	.03	1.50	0.253	1.45	12	2500	68	.006	10	8322
10	.03	1.50	0.247	1.55	8	2500	78	.004	10	8380
5	.07	1.50	0.247	1.45	12	2000	78	.006	5	8325
1	.07	2.50	0.247	1.45	8	2500	68	.006	10	8295
7	.07	2.50	0.253	1.45	8	2000	78	.004	10	8300
2	.03	2.50	0.253	1.55	8	2000	68	.006	5	8390
8	.07	1.50	0.253	1.55	12	2000	68	.004	10	8355
11	.03	1.50	0.247	1.45	8	2000	68	.004	5	8308

*Two dummy factors were used to complete the matrix

4. Results and analysis

The statistical analyses of the observed data were performed using the Design Expert software [11]. As a first step, estimated effects and the sum of squared deviations resulting from the changes made were estimated. These are shown in Table 3 together with the percent contribution of each factor to the total sum of squares.

As can be seen in Table 3, changes in both the speed of testing (**A**) and the width of the test specimen (**D**) appear to contribute the most to the total sum of squares.

Figure 4 represents a half normal probability plot of the absolute values of estimated effects with factors **A** and **D** selected for the regression model. Under this condition, the Plackett-Burman design was projected into three replicates of a full 2^2 factorial design. Table 4 represents the analysis of variance table for the projected design.

Table 3: Estimated effects and percent contributions

Term	Estimated Effect	Sum of Squares	% Contribution
Speed (**A**)	-37.17	4144.08	28.000
Grip Length (B)	8.833	234.083	1.581
Hole Diameter (C)	7.833	184.083	1.244
Width (**D**)	47.833	6864.083	46.370
Length (E)	14.500	630.750	4.261
Grip Pressure (F)	-5.500	90.750	0.613
Temperature (G)	22.167	1474.083	9.958
Hole Center (H)	6.833	140.083	0.946
Soak time (J)	-3.167	30.083	0.203

Table 4: Analysis of variance for the peak load

Source	SS	df	MS	F_o	P-value
Speed (**A**)	4144.083	1	4144.083	9.829	0.0120
Width (**D**)	6864.083	1	6864.083	16.280	0.0030
Residual	3794.750	9	421.639		
Lack of Fit	270.750	1	270.750	0.615	0.4556
Pure Error	3524.000	8	440.500		
Total	14802.917	11			

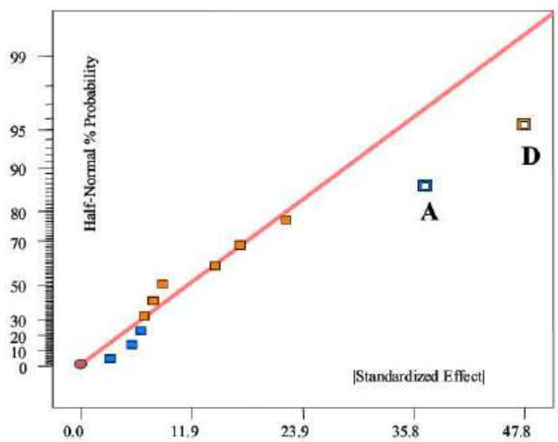

Figure 4: Half normal probability plot

As shown, the interaction effect between speed and width is not significant as indicated by the lack of fit test with a single degree of freedom.

Both the speed and width are significant with reported p-values of less than 5%. These results confirm that the test procedure is sensitive to changes in the speed of testing and width of the test specimens. The fitted regression model representing the average peak load in terms of the two factors is given by:

E(Peak load) = 7673.38- 929.17*Speed +478.33*Width

Diagnostic examination of the residuals revealed no violations of the underlying assumptions regarding the error variance. As indicated, the fitted model is significant with a p-value of 0.0022. The reported value of the multiple coefficient of determination R^2 implies that the model can explain 74 % of the variation in the observed peak load. Both the adjusted R^2 and the adequate precision values indicated that the model can be used to navigate the design space.

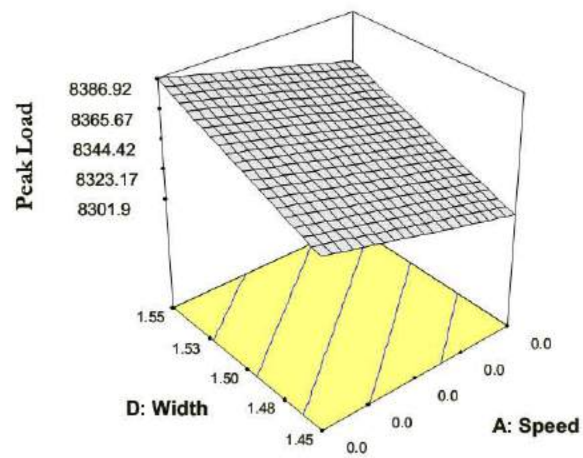

Figure 5: Three-dimensional peak load response surface

Figure 5 shows a three-dimensional plot of the fitted model. As shown, an increase in the width of the test specimen tends to increase the average peak load at failure. This can be explained by the consequent increase in the cross sectional area of the test specimen. Also, Figure 5 indicates that increasing the speed of testing has an adverse effect on the average peak load. A significant reduction of the average peak load is observed at the high level of speed.

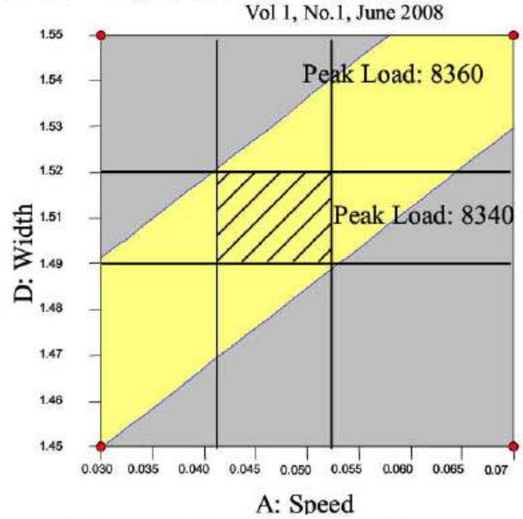

Figure 6: Overlay plot with recommended limits

The overlay plot shown in Figure 6 was prepared by restricting the average peak load within 8350 ± 10 pounds. This range of measurements can be achieved by maintaining the width (D) between 1.49 and 1.52 inches and the speed of testing (A) between 0.042 and 0.052 in/min.

To verify these results, three additional specimens from the original panel were prepared with a width of 1.51 inches and tested at a speed of 0.045 in/min. As shown in Table 5, the results fell with the estimation and prediction intervals shown in Table 6.

Table 5: Confirmation test results

Specimen #	1	2	3	**Average**
Peak Load (Ib)	8375	8350	8400	8375.0

Table 6: Confidence limits for estimation and prediction of peak load

	Prediction	**SE Mean**	**95% CI low**	**95% CI high**	**SE Prediction**	**95% PI low**	**95% PI high**
Peak Load	8361	7	8345	8376	22	8312	8409

5. Conclusions

This research was aimed at evaluating the ruggedness of the open-hole test procedure. Nine factors were identified and a Plackett-Burman design with 12 runs was used to screen their effects. Levels of these factors were selected based on the tolerances specified by the ASTM standards D3039/D 3039M. The statistical analysis indicated that the test procedure was sensitive to changes in both the speed and the width of the specimen tested. A graphical technique was used to establish tighter limits for controlling these factors and hence improve consistency of the test results. These limits were reported to the laboratory for implementation in future testing. While extrapolations of the aforementioned results are not recommended, the methodology utilized in this research can be followed to study other test procedures.

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Toward a Historically-Informed Framework for Teaching Operations Management

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Abstract

We propose a pedagogy for operations management (OM) framed in terms of the history of operations practices. The framework identifies three distinct OM traditions—craft production, mass production, and contemporary—and captures some key interrelationships between them. We also identify five key dimensions of OM practice: job/work unit specialization, batch size, quality control, product/process design, and supplier relationships. The three OM traditions are contrasted on each of the five dimensions of OM practice.

The majority of OM academic texts are organized by OM sub-functional topic area, and often present concepts and techniques without a powerful sense of historical context. Because students are drawn to narratives and stories, our pedagogy gains its effectiveness by using historical accounts that contextualize OM ideas and methods. Also, by drawing conceptual threads across topic areas using the five dimensions listed above, students learn to cross sub-functional topic area borders, breaking out of "silo-like" thinking. Finally, we argue that contemporary OM practices are not a rejection or overturning of past models. Instead, they include and subsume earlier traditions of practice, hybridizing some aspects of those practices while attempting to confront and correct for some of their pitfalls.

1. Introduction

The impetus for this paper can be found in the accumulated experiences of an 18-year period teaching introductory operations management courses to both undergraduates and MBA students. Over this period, we have had about 3000 students pass through these courses.

The vast majority of OM academic texts used in introductory courses tend to be organized by functional sub-area. For example, Heizer and Render [2] begin with chapters on operations strategy and forecasting and march through quality management & control, facilities layout, inventory management & control, aggregate planning, scheduling, etc. Some minor sequencing differences aside, Stevenson [4] follows a very similar format. While this provides a convenient and clean way to organize material from a large discipline, it has one important drawback: it tends to divide up the material, often too neatly, into sub-functional silos. More and more, contemporary OM practitioners are endeavoring to break down such functional and sub-functional barriers in order to improve communication and quicken response to customers. The organization of most academic texts, instead of mirroring these important shifts in practice, tends to continue emulating an older paradigm that reinforces the rigidities of functional organization.

There is a second, critical aspect in which we frequently find academic texts lacking: they often present OM techniques and methods without a great interest in historicizing them. In a typical introductory academic text, a sensitivity to the history of the OM discipline, if it exists, is usually found in the earlier chapters which deal with broader conceptual topics like a general introduction to the OM field, operations strategy and process management. Once we move from strategy to tactical and operational decision-making, techniques are frequently presented with little or no sense of historical development or context. This has the unfortunate result of cutting off the state of contemporary practice from a sense of the historical trajectory of development of the discipline.

In a survey of 16 OM textbooks, Wilson [5] discovered that the focus was almost exclusively on current issues. The few nods to history, most frequently to the work of Adam Smith, Eli Whitney or Frederick Taylor, were marked by superficial coverage with little critical discussion of the impact of these figures on the field. Wilson also critiques textbooks for paying little attention to identifying "precursors of operations management ideas, thinkers, activities, or systems." Further, he asserts that OM is anomalous in this regard; fields like accounting, economics, and even operations research have done more work to investigate the historical origins of their discipline.

Nieto, Arias, Minguela and Rodriguez [3], in research analysing the contents of recent OM texts, find that academicians in the field have been inordinately devoted to the development of quantitative techniques. They believe that this narrow focus has limited the development of OM as a field. Our historical framework thus attempts to correct for this limited focus by placing OM against the broad canvas of its historical development.

Hayes [1] proposes a system of differences in OM between the "Old Economy" and the "New Economy." The latter economy is marked by the building of strong relationships with customers and suppliers, a supply-chain-management focus, and the importance of speed and quality. Hayes' two economies mirror, respectively, the mass production and contemporary practices proposed in this paper. Hayes' model further provides a firm rationale for the use of a historical context while teaching OM.

2. History lessons

"History is more or less bunk." – Henry Ford
"Progress, far from consisting in change, depends on retentiveness...Those who cannot remember the past are condemned to repeat it." – George Santayana

In their views of the importance of history, the above statements occupy opposite poles of the spectrum. It is understandable that reasons of pragmatism and efficiency force most academic OM texts to pay short shrift to historical context and development but in doing so, they find themselves sliding closer to Ford's and further away from Santayana's view of the usefulness of history.

Students who are initiated into the discipline in this fashion begin to view contemporary practices as existing 'out of time', disconnected from the past. But in fact, present practices are the result of a ceaseless movement driven by response or reaction to, and, sometimes rejection of past practices. Tracing this history allows students to see the multitude of challenges faced by OM practitioners in the past, and the manner in which these challenges were confronted and surmounted. An account of these historical encounters holds valuable lessons for contemporary and future OM practice. Our students will be in a position to influence the future of OM practice, and we hold that they will be more resourceful managers if they possess an awareness of history and the challenges it has posed to the discipline over time.

3. A Tension between perspectives

In our introductory OM courses, we have addressed the two key drawbacks of most academic texts—lack of sensitivity to the history of the discipline, and replicating the idea of sub-functional silos in their organization of chapters—by using both a primary text, authored by an academic scholar in the field; and a supplementary text authored by a practitioner. While the primary text has varied, the supplementary text has most often been Womack, Jones and Roos's *The Machine that Changed the World* [6].

We take the first four weeks of the semester to read Womack et al. [6], while simultaneously covering the introductory, strategic-oriented chapters of an academic text like Heizer and Render [2] or Stevenson [4]. By reading these texts in tandem, we attempt to set in motion, early in the course, a process of cross-fertilization between these two perspectives that will continue for the rest of the course.

The academic text begins by initiating the student into the basic vocabulary and conceptual frameworks employed by the discipline, and the practitioner text immediately illustrates the application of the lexicon in the discipline, bringing it down to earth and putting it to work in an everyday OM context.

Thus, through the course of the semester, by oscillating between academic and practitioner perspectives, we are involved with students in an activity of continuous synthesizing. This is not an activity that only provides clarification, reinforcement and harmony but also results in clashes and contradictions between theory and practice. Thus the texts are held in the student's mind in a permanent tension that lasts all semester long. It is important for students to experience and live with the knowledge of the contradictions between these two perspectives; these tensions and contradictions should not be permitted to be resolved away quickly and simplistically.

4. The power of stories

There is another important way in which Womack et al. [6] is different from the typical academic text: it is a great example of absorbing storytelling. The book relates the history of auto production, dividing it into three stages: craft production in Europe in the late 19th century; mass production spearheaded by Henry Ford in America in the early 20th century; and lean production, pioneered by Toyota in Japan beginning in the 1950's.

From this story is fashioned a strong, dramatic narrative that employs rich detail at every turn and moves forward with momentum. Our students report, invariably, that they find the book accessible and riveting. Not only are they more eager to complete their reading assignments from this book rather than the academic text (which, nevertheless, they also must read), they seem to remember the book better. In OM elective courses that follow the introductory course, they are able to recall ideas and details from the book more vividly than some essential concepts from the academic text.

Time and again, through the example of this book, we have noticed the power of stories to convey concepts and techniques in a way that makes them more likely to be understood and retained by the student in the long run.

5. Traditions and dimensions of OM practice

Taking our cue from Womack et al. [6], we identify, in the course, three traditions of OM practice: craft production, mass production, and contemporary. As we move through the semester, we contrast these three traditions on the basis of five dimensions of OM practice: job/work unit specialization, batch size, quality control, product/process design, and supplier relationships (see table 1).

The three traditions provide a linear, chronological basis which helps illustrate that ideas and methods are not born in a vacuum, free-floating and disconnected from the past, but instead in a concrete and specific response to earlier practice. This impresses upon students the strong sense of how the present responds to the past, draws from it, and attempts to advance beyond it, in a step-by-step fashion.

Employing a historical approach that makes use of narrative is one key benefit of the approach we propose in this paper. The second important advantage of our method is the emphasis on countering the sub-functional silo-like organization of the typical academic text. The above five

Table 1

Traditions & Dimensions of OM practice	Craft production	Mass production	Contemporary
1. Job/work unit specialization	Small craft shops, unspecialized work performed by owner-workers	High levels of specialization	Cross-functionality of labor and moderate levels of specialization
2. Batch size	Small, often a size of one.	Large lots of a small variety of components	Small-to-medium batches made possible by quick changeovers. Linked closely to customer demand.
3. Supplier relationships	Close and long-term	Multiple sourcing: short-term and antagonistic	Single sourcing: Long-term, collaborative, tiered supply
4. Quality control	Hampered by absence of standardization	Reliance on final inspection	"Quality at the source" and process control
5. Product/process design	Product proliferation and difficulty in perfecting product or process design.	Learning curve benefits from refining designs of a small variety of products.	Flexible processes, mass customization.

dimensions of OM practice allow us to accomplish this. For example, ideas related to batch size belong not just to the purview of one topic area but to several: process management, inventory management, quality management (failure costs of quality like scrap and rework), JIT systems (small, frequent batches) and facilities layout (cells and small batches).

So, the five dimensions of OM practice become recurring motifs that continue to reappear in various chapters. A concept like batch size can cut across an array of OM sub-topical areas, thus establishing continuities that undercut rigid, silo-like divisions between chapters organized by sub-topic in the academic text.

For the rest of this paper, we will detail this pedagogical framework built on three traditions and five dimensions of OM practice.

6. Dimension #1: Job/work unit specialization

Since we begin the course with craft production, the first of the three traditions of OM practice, students are introduced at the start to the idea of work in its unspecialized form. Assembler firms—like P & L, the Paris-based firm that was the world's largest automaker in the late 19^{th} century—subcontracted out the production of the various components of a car to many machine shops scattered around Paris.

These shops, which were small in size, were often family businesses run by owner-workers who were apprenticed into the business at a young age and progressed to a full set of a wide range of skills over time. Since each automobile was custom-made, these owner-employees needed to possess a reasonably broad range of skills, a need further enhanced by the overwhelmingly labor-intensive nature of manufacturing at the time.

The assembler had an acute need of a different kind of unspecialized employee: the valuable skilled fitter who would force components to fit during assembly because component makers did not always employ a standard gauging system.

Often, students enter the OM course with a mental picture of large, monolithic operations that use armies of unskilled workers on assembly lines, making identical products in large volumes. So, beginning the course with a treatment of the craft production roots of the auto industry helps correct that impression. The next phase of auto production, pioneered by Henry Ford, is indeed more in line with the students' stereotypical view of manufacturing that features specialized, low-skilled workers performing narrow tasks.

Thus, it is useful for students to see that contemporary practice, influenced by lean production ideas, has tried to draw from both of these opposing practices. It accomplishes this by introducing, into high-volume/low-variety production environments the need for cross-functionality and team-work which counter the excessive specialization of mass production.

7. Dimension #2: Batch size

There are certain critical aspects of a manufacturing system that don't fit neatly into any one sub-functional area of OM, and instead disperse their effects across the entire operation. Batch (or lot) size is one such aspect. Most students do not recognize the large and pervasive impact of batch size, which they initially think of as simply one variable in a large production planning system. Tracking the historical changes in batch size over the course of a century in the auto industry helps drive home its crucial impact on efficiency and competitiveness.

Both component parts and finished automobiles were produced in extremely small lots (often a lot size of 1) in craft production. This also applied to expensive aftermarket replacement parts which had to be special-ordered. Because craft shops used flexible (or general-purpose) equipment, the total time spent on changeover was significant both because the lots were small and because machine tools were still in the earlier phases of their technological development. The result was high per-unit costs and also high manufacturing lead times.

Mass production proposed a bold solution by slashing product variety, and designing and deploying special-purpose (inflexible) equipment, thus making significant reductions in manufacturing lead times. However, batch sizes were relatively large in such a system, leading to high levels of (just-in-case) inventory.

Contemporary systems have tried to operate in a middle ground of lot size between the extremes of craft and mass production. With investments in process R&D that have allowed reductions in changeover times, smaller batches have become possible.

This push toward continuously reducing changeover times has had an explosion of benefits. This is the perfect juncture for us to introduce them to students. In fact, this class session is conducted with a great deal of small-group and large-group discussion, nudging students to reason through and identify all the benefits (at least a dozen of them) on their own, rather than simply presenting them to the class.

It begins to dawn on students at this point that batch size has a large and far-flung impact inside the organization. Small batches allow for numerous advantages. When quality errors occur, fewer units are affected, leading to lower rework and scrap costs. A smaller lot lends itself to manual handling by the worker, who is then more likely to spot quality problems with a batch, and take steps to fix the underlying cause quickly. The result is better "quality at the source." Mixed-model production—making numerous products each day, each in small quantities-better matches patterns of supply with patterns of demand. Finally, small batches result in faster response to customers. Gathering these threads across operational sub-functional areas (quality, production planning, production control, scheduling) gives students a deeper appreciation for the widespread effects of batch size reduction.

8. Dimension #3: Supplier relationships

Tracing the nature of the relationship between supplier and buyer firms over the course of the last one hundred years in the auto industry proves to be an illuminating exercise for students.

Craft assemblers in the auto industry had steady, long-term relationships with their suppliers, the small shops that custom-made components for them. Despite this closeness, component parts required extensive rework in the form of "skilled fitting" before they could be assembled into the automobile. This unfortunate inefficiency was the direct result of an absence of standardization both in terms of component parts and (more importantly) systems of gauging. Thus, while close supplier relationships existed, they did not often result in quality or lead time benefits.

The use of multiple sourcing in mass production drastically changed the nature of supplier relationships, making them temporary, antagonistic and fraught with mistrust. In marked contrast to craft practices, in which suppliers were given design responsibilities for various portions of the automobile, mass producer-assemblers retained complete control over design activities, sharing as little of the design details with their suppliers as they needed to. The paramount importance of the criterion of price in awarding supplier contracts meant that several other critical supplier performance measures—quality, delivery, responsiveness to special requests—suffered.

Contemporary practice has worked to reduce supplier base and deepen supplier relationships by moving towards single sourcing, thus building trust. This has made it easier to implement a tiered supply chain in which design and manufacturing responsibilities are delegated to various tiers and tier members.

Once again, students notice a return in the contemporary period to the emphasis on the relatively long-term relationships of a pre-mass production era, only within the context of improved technologies like standardization (of gauging systems, products and processes), improved systems of communication, and more powerful machine tool technologies.

9. Dimension #4: Quality control

Lack of standardization combined with high levels of customization meant that quality control (QC) was poor in craft production. There was little opportunity to perfect the production of components by riding the experience curve. Further, the proliferation of gauging systems made it difficult to build products precisely to customer specifications. Dimensional creep arising from "force-fitting" components in the final assembly stage also detracted from quality. It was often assumed that the average automobile owner had, on staff, a mechanic who would be able to perform the frequent repairs needed.

Mass production addressed these drawbacks by incorporating standardization not just of gauging systems but also of products and processes. Combined with the innovation of a customer Q&A manual that allowed cars to be fixed, for the most part, with a farmer's set of tools, the level of repairability of the product increased significantly.

The notion of specialization, which we track across sub-functional topic areas throughout the course, can be illustrated vividly through the example of mass production and quality control. Since mass production employs specialization as a founding principle, quality ends up being specialized as well, resulting in a reliance on final inspection conducted by the quality control department.

This is a perfect juncture at which to emphasize to students that lean production practices do not jettison or reject out of hand the principles of mass production. In fact, they build upon a foundation of these principles, making crucial modifications to correct for certain flaws like excessive specialization. This is accomplished in lean-influenced contemporary production practice by implementing quality control measures at every stage of the process. Authority and responsibility for inspection and testing lie as much with line workers as with a specialized group such as the QC department.

Thus, in quality control, the role of workers in contemporary practice harks back to the role of skilled owner-employees of a craft shop.

10. Dimension #5: Product and process design

Craft production in the early years of the auto industry featured high levels of product proliferation, because it offered extensive customization to customers. This meant significant design effort devoted to a wide variety of products. Opportunities to revise, refine and optimize product designs were thus limited.

By tightening the variety of components that needed to be produced, mass production exploited learning curve opportunities in product design. This was also true for process design since mass production restricted process variety, with narrowly specialized equipment forming the core of the production process.

We emphasize and illustrate to students at this point that the contemporary tradition of design practices has been influenced both by mass production and by craft production. On the one hand, mass production's innovations of standardization have seen widespread acceptance. But excessive standardization has its drawbacks: its inability to meet a wide range of customer needs, and its inflexibility to changes in those needs.

For students, the notion of mass customization represents a perfect illustration of contemporary practice's "synthesizing" impulses. Mass customization redesigns processes such that standardized components are produced first, and the processes of customization are postponed. This allows firms to both make a product that is tailored to customer needs and also extract savings from high-volume production of standard components. Further, by postponing the point of differentiation, firms are able to respond quickly and more accurately to customer demand.

11. Student reactions

Though we have not yet formally assessed it, in the 18 years that we have used this historically-informed framework to teach OM, we have received a significant amount of verbal feedback about our approach from students both during the course and afterwards. From this feedback, we can say that students seem to appreciate the approach for one or more of three reasons: (1) The "real-world" examples of Womack et al. [6] are immediately interesting and absorbing; (2) Historical context makes it easier for them to build a "big picture" of the OM field, which in turn helps them remember the course better after they graduate; and (3) It gives them a point of conversation to introduce and build upon during internship and job interviews, since OM practitioners are often familiar with Womack et al. [6].

12. Conclusion

Combining the use of academic and practitioner texts in an introductory OM course can result in a valuable process of cross-pollination that can benefit student learning. The ahistorical presentation of techniques and methods that is quite typical of academic texts can be complemented and corrected by the use of a practitioner text. Students respond to narratives; they remember stories. The result is enhanced learning, along with a fruitful reconciliation of academic work with practitioner concerns. At the end of the course, the students are able to form, in their minds, a fuller and more complex picture of the OM discipline.

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A Flow Direction Algorithm for Geometry-Based Networks which Utilizes a Prioritized Breadth First Search Algorithm

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Abstract

Given a series of two-dimensional regions that compose a three-dimensional map, a flow network is generated by considering the regions as nodes and the interconnections as edges. An algorithm to direct flow across that network with the intent to maximize throughput and minimize the number of hops is presented in this paper.

1. Introduction

The evacuation and egress of large groups of people from structures is sometimes difficult to study primarily due to problems of scale. Namely, when considering thousands of people, it is difficult to arrange for volunteers to re-enact the situation. Additionally, accurately observing and recording the evacuation or egress of a large structure is difficult and costly. The reasons for wanting to study these are many; but most revolve around the preservation of human life by maximizing the speed and efficiency with which people evacuate a building in the event of some dangerous situation [6, 10].

An obvious way to avoid these difficulties is to simulate the situation with a computer model; however, the simulation of thousands of individuals limits the computational complexity of each individual (for examples, see [4, 5, 7, 9, 10]).

This algorithm was borne out of an attempt to simulate this sort of egress from a university stadium. The initial target stadium modeled was "The Rock," the football stadium at The University of Southern Mississippi in Hattiesburg, MS. Figure 1 illustrates the walkable surfaces that were derived from this stadium. In order to simplify computation, the decision was made to treat it as a series of two-dimensional, interconnected *slices*, rather than as one contiguous three dimensional form. The term "slice" refers to a cross section of the geometry, such that everything can be translated into two dimensions without any ambiguity resulting from two pieces of geometry occupying the same position. For example, a slice of most buildings is synonymous with *floor*.

Once partitioned into slices that are strongly connected, the next step in navigating the three dimensional map is to identify any *exits* from the current slice and navigate toward them. The mechanism for doing this is beyond the scope of this paper, but the assumption is that it is a least distance algorithm simply for the sake of convenience. For example, given a position and

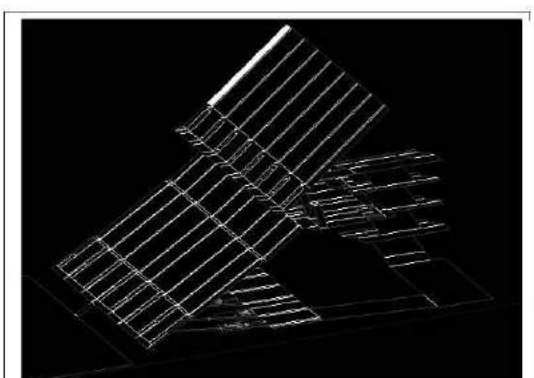


Figure 1. Walkable surfaces of "The Rock"

an exit, a person, or agent as it will be referred to hereafter in this work in order to distinguish simulated people from real individuals, has a route to reach the exit of a given slice.

This minimum distance patching works but leads to several problems due to the bi-directionality of the connections between slices. First, agents would infinitely iterate back and forth across a connection. Secondly, the navigation of an individual slice doesn't always make sense when the overall map is considered. The solution decided upon was to make the connections unidirectional. That is, if a given section *A* is connected to a given section *B*, then section *B* is not connected to *A*. Our proposed algorithm directs these undirected links.

A more formal statement of the motivations that resulted in the creation of this algorithm is presented in section 2. In section 3, we formally present the algorithm, and show initial results and complexity analysis in section 4. We discuss future work in section 5.

2. Motivation

In section 1, the problems associated with an undirected (or bi-directed) graph were mentioned. The first problem, that of agents infinitely iterating back and forth across a connection, is due to the fact that providing lookahead or memory introduces computational and memory requirements that do not fit into the constraints of the problem area. Namely, the goal is to simulate a very large number of agents, thus the individual agent memory and computational requirements must be minimized. Given that memory of previous paths traversed is not provided, nor is looking ahead beyond the current decision supported, an agent does not realize that the entrance from which it exited in the previous time step is not in fact the nearest exit from the current area. To put this in a real world example: imagine that a person entered the lobby of a hotel from an elevator. The elevator, which was just exited, is the quickest path out of the lobby; however, entering it makes no sense if the person is trying to exit the hotel. Yet, if this person had no idea that they had been in the elevator previously, nor did they know that the elevator led further into the building, then entering the elevator makes perfect sense.

Secondly, without a precomputed path or lookahead, an agent has no idea of the number of slices between it and the global exit (or sink); the agent does not know if moving across a given exit will move it closer to the global exit. A further, more complicated problem exists: in some situations it is illogical to traverse a given slice. Possible reasons include congestion, capacity, and level incline with reference to stairwells.

Our proposed algorithm attempts to solve these issues by allowing one way connections between slices. The fact that a given slice *A* is connected to a given slice *B* does not infer that one can travel from *B* to *A*.

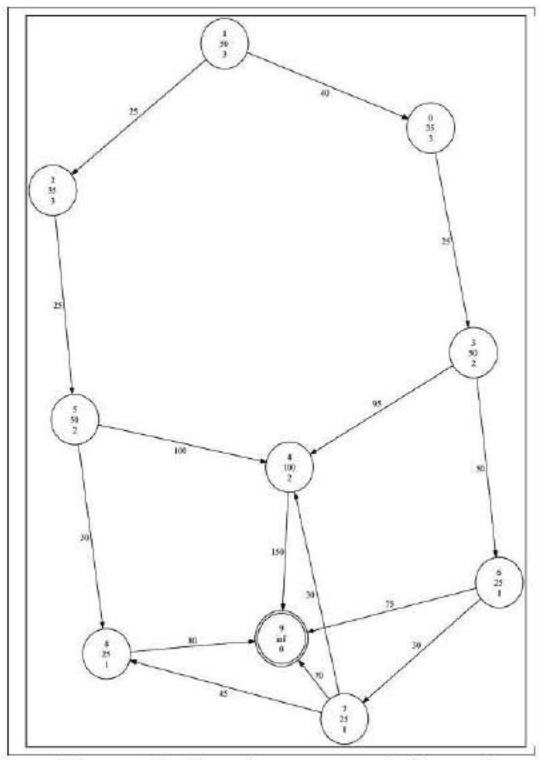


Figure 2. Graph representation of "The Rock"

The first step in attempting to solve our problem inevitably led to the mapping of our geometry to a more appropriate graph representation. This is done by considering each slice as a vertex and each connection between two slices as an edge. The stadium map of Figure 1, for example, is converted to the graph of Figure 2. Further, capacity of a vertex and an edge can be derived from a variety of data. An obvious abstraction is to consider the capacity of a vertex to be its area, and the capacity of an edge to be the capacity of the *portal* between the edge and the slice. Other abstractions are possible, and it is left to the reader to decide upon a suitable one. Also, the slice that contains the global exit of the map, the structural exit, can be consider the sink.

3. Algorithm

It is assumed that there are never any negative or zero value weights of any kind. In the target application, considering that the graph is derived from a real geometry, negative or zero value capacities are nonsensical.

Given an undirected graph $G(V, E)$, with node capacities c_n, positive edge capacities k_n, z-values z_n specifying a vertical (or third-dimensional) component to each node, and a minimum of one node labeled as a sink $(c_i = \infty)$; our algorithm is as follows:

1. Perform a breadth first search (BFS) [1] to determine the minimum distance, d_i, from each node, v_i, to a sink. Clearly, $d_i = 0$ for all sinks.
2. Compute the weight, w_i, of each node such that $w_i = c_i + \sum_{e \in E'} k_e$, where E' is the subset of edges that directly connect to node v_i.
3. Sort the nodes in the following order:
   3.1. Descending order by d_n.
   3.2. Ascending order by w_n.
   3.3. Descending order by z_n. Note: if, for two nodes v_i, v_j, the weights w_i, w_j are within z_t (the z-tolerance), then steps 3.2 and 3.3 are reversed.
   3.4. Ascending order by c_n.
   3.5. Lexicographical order by node id (typically, just an integer, *i*).
4. Enqueue each node in sorted order to Q. It will be necessary to include all sinks since there may be an edge connecting two sinks that must be directed. Sinks are typically enqueued in lexicographical order unless their z-values differ, in which case sinks with larger z-values will flow out to those with smaller z-values.
5. Process the queue, one node at a time, directing all undirected edges out of the current node. If an edge is already directed, it is not modified.

Node weights have precedence over z-values because if one node has much greater weight than another, then irrespective of z-values it might be desirable to flow into that node. If two nodes are within z_t (the parametrized z-tolerance), then z-values take precedence over node weights.

Initially, given two node weights, w_i and w_j, the percent difference, p, of the two nodes was given by the following:

$$p = \frac{\frac{(w_i - w_j)}{w_i} + \frac{(w_i - w_j)}{w_j}}{2}$$

This was found to be slightly inaccurate; therefore, the determination of two nodes being within z_t of each other is at present obtained by evaluating the following compound condition:

$$\frac{max\{w_i, w_j\}}{min\{w_i, w_j\}} \leq 1 + z_t$$

and

$$\frac{min\{w_i, w_j\}}{max\{w_i, w_j\}} \geq 1 - z_t$$

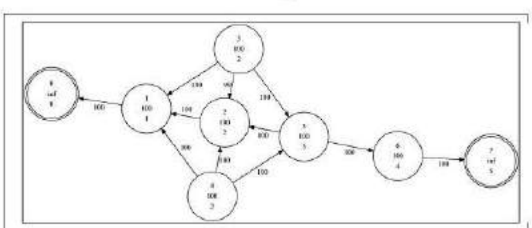


Figure 3. A graph generated to test z-tolerance

In testing the z-tolerance parameter, we designed the graph illustrated in Figure 3.

4. Results and complexity

The algorithm was implemented in C# and executed on both the Windows and Linux operating systems. Code was designed to randomly generate graphs (as in Figure 4) of various sizes with random weights that conform to our assumptions.

Graph 1 illustrates the average execution times for random graphs of exactly 10, 50, and 100 nodes. The average execution time converges at approximately 100 to 1000 iterations. For 100 nodes, the algorithm is quite fast, which would be an atypically large graph for our target area: it only takes, on average, 0.0009 seconds to execute the algorithm.

For a given undirected graph, the algorithm iterates through each node, V. Isolating all sinks, a BFS is performed from each sink to every other node. If t is the number of sinks, then in total, t BFS algorithms are executed. The complexity of BFS is given to be $O(V+E)$ [1], thus yielding the complexity of $O(t(V+E))$ to calculate every node's minimum distance to a sink.

Node capacities and z-values are integral to the node, so no time is spent calculating those.

Next the algorithm iterates through each node and computes edge capacities and weights. Node weight is defined to be the sum of all the node's directly connected edge capacities and it's own capacity. The complexity of computing the node weights is $O(VE)$, since for each vertex, V, each edge, E, is explored.

Finally, the table is sorted with a complexity of $O(V)$. In total, the complexity of the algorithm is: $O(t(V+E))+O(VE)+O(V)=O(VE)$.

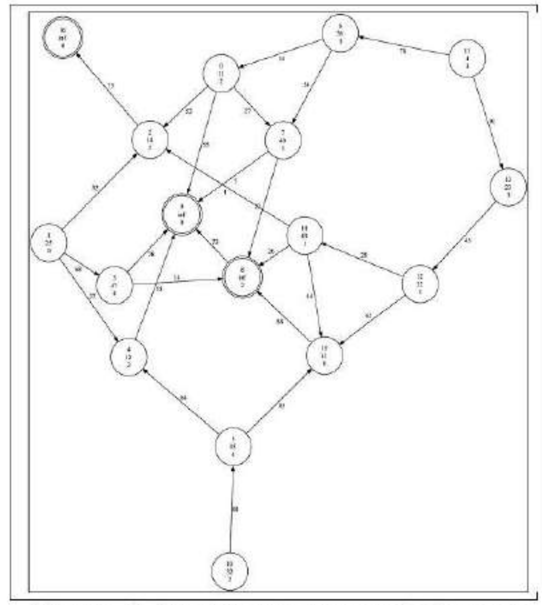
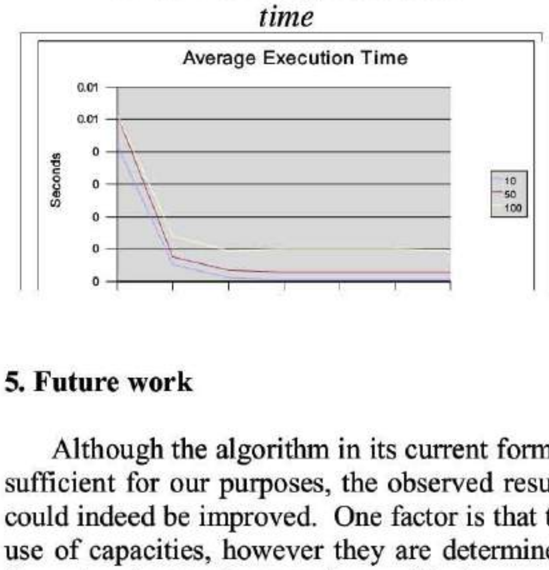


Figure 4. A randomly generated graph

Graph 1. *Average execution time*



5. Future work

Although the algorithm in its current form is sufficient for our purposes, the observed results could indeed be improved. One factor is that the use of capacities, however they are determined, do not make much sense in considering a real system. For instance, attributes such as relative distance and relative incline combine to play a part in deciding what path to take. Certain crowd groups might prefer the gentle incline of a ramp to the steep incline of a stairwell, although the ramp has more surface area.

It is possible to use probabilities to determine a service rate for each vertex and edge, and run the algorithm based on those rates rather than the capacities. This would allow us to consider things such as incline (its effect on movement rate) as well as actual surface area and the width of a passage when considering the number of agents that can flow through it in a given period of time. [8]

Another area of further research is the idea that different groups of agents might weigh some factors differently. One possible way to incorporate this would be to have one flow graph for each population type.

Additionally, the capacities and/or service rates may vary. Although it would be possible to get an average value for the service rate over a broad period of time, it may be better to continually recompute capacities or service times for each node, and re-execute the algorithm to change the flow graph dynamically based upon the state of the entities within the map.

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Ergonomic Analysis of a Hair Salon

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Abstract

Cosmetology involves a number of diverse tasks that have been implicated in cumulative trauma disorders and in other workplace injuries. This case study presents an analysis of injury risk and prevalence in a salon. Individual, occupational, and organizational factors are considered, and potential areas where risk can be reduced are presented.

1. Introduction

Cosmetologists are at risk for a variety of work-related injuries. Their job is characterized by standing for prolonged periods of time in awkward body postures, handling a variety of chemicals, and undergoing repetitive hand movements. Cosmetologists' workplace injuries have been studied extensively throughout the world [1], [2], although few studies have been conducted in the United States. While attention has been given to the ergonomic design of scissors [3], there are many other tasks performed by hair stylists in the course of a normal day including: shampooing, mixing, applying color, drying, and styling.

Cosmetology is different from most occupations requiring hand tool use and repetitive actions; stylists take much pride in their creative work, and often favor quality work over personal safety. Individual differences in safe behavior may also exist.

The study described here was an ergonomic evaluation of an Orlando, Florida, area hair salon. This study examined levels of risk at the task, organizational, and personal levels. Because we examined a single salon, organizational factors may not be widely generalizable, but we feel that potential problem areas found in one salon can be a starting point for a more systematic investigation of salons in general.

1.1 Literature review

Several potential sources of workplace injury were examined. Specifically, we considered contortions of the wrist and hands while using tools, time spent standing and bending, and exposure to chemicals in styling products and hair coloring products.

The use of scissors is one area of workplace risk and injury in a hair salon. For example, it is reasonable to expect that ergonomically designed scissors can help alleviate wrist and hand pain when compared to normal scissors. Indeed, Boyles, Yearout, and Rys described a new design for scissors that could be used to reduce the amount of time stylists bend their wrists [3]. Cosmetologists may also suffer cuts and lacerations due to hitting the non-dominant hand with the scissors during certain types of cutting actions [4]. Improved scissors with rounded tips, for example, may reduce this risk.

Contact dermatitis on or near the hands and wrists is also prevalent among hairdressers. Almost 60% of hairdressers surveyed in Melbourne, Australia, had experienced some change in their hands since beginning the profession [5]. Uter et al. found a significant difference in prevalence of dermatitis and skin allergies in cosmetologists when compared with other occupations [6]. The use of gloves for certain tasks, such as mixing dyes and shampoos, is important in preventing these conditions. Kang et al. found similar results among hairdressers with the addition of a higher prevalence of musculoskeletal disorders and respiratory problems in hairdressers then in the general population [1].

The musculoskeletal disorders experienced by cosmetologists are primarily cumulative trauma disorders (CTDs). A study by the Korean Group for Occupational Medicine demonstrated that pain among hairdressers was distributed as follows: 61% complained of shoulder pain, 59.9% of neck pain, 53% of lower back pain, and 42% of hand and wrist pain [7].

Contortion of the upper body during certain tasks can also result in CTD. Tooru et al. examined changes in trunk inclination angle (TIA) between stylists operating either behind or to the side of a shampoo bowl [8]. It was determined that standing behind the bowl placed less stress on the body's trunk.

Despite mostly satisfactory ergonomic conditions in salons, the "high peak of concentration of chemicals during dying, bleaching, permanenting and hair spraying still pose a significant health problem" [2]. Stations in which chemicals are mixed or applied should be well-ventilated, providing sufficient air exchange to remove potential irritants.

Given these potential sources of injury, the purpose of the study was to evaluate occupational risk in a specific salon in the United States. The influence of personal, environmental, and organizational factors on workers' health was also examined.

2. Methodology

2.1 Equipment

To facilitate data collection, several surveys and interview aids were employed. CTD risk was measured using the fuzzy hierarchical model described by McCauley-Bell, Crumpton, Crumpton-Young, and Wang [9]. This model was used because it includes factors of both the individual and the environment. Because some factors are consistent across the workplace and others are unique to the individual stylist, we found it necessary to separate these factors and measure them using two separate instruments.

The first was a pen-and-paper demographics questionnaire. This asked information such as age, gender, and time on the job. Individual CTD risk factors were also collected on this form. Finally, participants were asked to rate the incidence of a number of injuries common to stylists that were identified in the literature. Responses were requested on a scale from 1 to 7, with 1 indicating "never," and 7 indicating "always." The items investigated are presented in Table 1.

Table 1. Types of injuries included on the demographics form

Respiratory Problems	Pain in Lower Back
Skin Irritation	Pain in Hands
Cuts or injuries during scissor use	Pain in Wrists
Pain in Neck	Pain in Arms
Pain in Shoulders	Dizziness

The second instrument was a workstation checklist adapted from OSHA ergonomic recommendations [10]. This quick yes-or-no checklist was designed to highlight potential problem areas.

The third instrument used was a hand tool evaluation checklist derived from a reference text [11]. This open-ended questionnaire guided researcher observations of potential hazards in using a hand tool. This was especially relevant to our study because hairstylists have a high degree of hand tool use.

The final instrument used was a count of trunk inclination adjustments. A ten-minute interval was specified during which the researcher counted the number of times the participant bended at the waist.

2.2 Participants

The target population was composed of the stylists working at an Orlando area salon. Our sample of this population consisted of the seven cosmetologists working during a two-hour period, 1 male and 6 female. The participants ranged in age from 22 to 34 years. The mean age was 27 years. The stylists ranged in overall experience from 1 year 11 months, to 11 years. The mean length of experience was 6 years.

2.3 Procedures

The goal of the data collection was an ergonomic analysis that was as comprehensive as possible. To that end, surveys, researcher observations, and one-on-one interviews were administered. Each participant was explained the purpose of the project and asked if they would volunteer to participate. No participant declined to participate. The demographics and personal CTD risk questionnaire was given for the participants to complete first. Following this, we explained that we would be making observations while the participant worked.

The researcher observations for each participant included the TIA count for a ten-minute period and task-related factors for CTD.

Observations were also made for the organization. Organizational CTD risk factors were recorded with insight from the salon's manager. A hand tool evaluation was completed for scissors, a flat iron, the hairdryer, and a clipper.

Finally, qualitative data was collected from individual interviews. Each participant was asked their opinions regarding the configuration and use of their work areas.

3. Analysis

In order to draw the most meaningful conclusions given the size of the sample, a correlation analysis was performed for each pair of quantitative variables of interest. Demographic variables included age, gender, work experience, smoking habits, and number of healthy hobbies. Symptom-related variables included preexisting diagnoses for CTD, diabetes and thyroid conditions, and complaints of respiratory problems, skin problems, hand cuts, neck pain, shoulder pain, lower back pain, pain in the hands, wrist pain, arm pain, and dizziness.

Variables related to the nature of the job tasks included the following: shift length, break length, use of gloves, and proportion of time spent cutting, shampooing, mixing, applying color, drying hair, and other. Finally, the number of trunk inclination adjustments was included.

CTD analysis was performed according to the method described by McCauley-Bell, Crumpton-Young and Wang [10]. Analysis of the workstations, hand tools, and interviews was done qualitatively and is described below.

Trunk inclination adjustment scores were divided by 10 for each participant to obtain the average number of TIA changes per minute.

4. Results

4.1 Quantitative correlations

Significant correlations from the correlation analysis are presented in Table 2. All results are significant at the $p < .05$ unless otherwise indicated. For clarity, only significant correlations are shown.

4.2 CTD risk

CTD risk was assessed using the model weights specified in McCauley-Bell, Crumpton-Young and Badiru [9]. Participants 1 and 2 ended their shifts before their individual risk factors could be assessed and were omitted from the analysis.

The mean score was 0.48. This is described as average risk. "Individual may experience minor musculoskeletal irritation on a regular but not excessive irritation" [9].

Table 2. Results of correlation analysis

Variables		Spearman's rho
Healthy Hobbies	Age	.89
Healthy Hobbies	Gender	.878
Work Experience	Pain in Neck	.805
	Pain in shoulders	.787
Arthritis	Pain in neck	.804
	Pain in shoulders	.827
Respiratory complaints	Time spent shampooing	-.816
Skin problems	Pain in hands	.790
	Pain in neck	.780
Hand cuts	Shift length	.845
	Preexisting CTD	.941

4.3 Workstation evaluations

In the salon studied, five stations were set up according to task. Stylists did not have their own work areas at the stations. Instead, all areas are shared. These stations are clusters of work areas for haircutting, styling, shampoo, applying hair-color, and mixing hair-color. The ergonomic workstation checklist was used for each station.

The shampooing workstation seemed to be well-designed, with the stylist being positioned behind the shampoo bowl. The literature suggests that this is physically less stressful compared to standing on the side of the bowl. All equipment was placed within easy reach. The tilt angle of the bowl is adjustable, but the workstation was otherwise unable to be repositioned. This could lead to problems, depending on the height of the stylist.

The haircutting stations and hair coloring stations were generally congruent with our ergonomic checklists. Minimal amounts of twisting and bending were required due to the close placement of tools and supplies. Fixed-height chairs and tables were observed at the hair color station, which could put stylists in uncomfortable positions, again depending on their height.

The "mixing lab" was an area where stylists prepared hair dye and other chemical treatments. The workstation analysis revealed several problem areas, including fixed work surfaces and sharp edges. All chemicals were stored on shelves along the wall, sometimes requiring reaching up high or low to access chemicals or tools.

Finally, we found air vents throughout the building providing airflow to each workstation. The "mixing lab" was expected to be problematic because it was enclosed, but we found that the wall did not continue to the ceiling, allowing for adequate ventilation.

4.4 Hand-tool evaluations

We first examined a pair of scissors. This tool has been the focus of much research and concern over hazards associated with cuts, wrist position, and pinching. Generally, the scissors allows the user to maintain a straight wrist and has a moderate pinching risk. Some were rounded at the tip to avoid hand cuts. However, each stylist typically owns his or her own pair(s) of scissors, based upon personal preference and cutting style.

The hairdryer is another frequently used tool. The salon manager explained that stylist preferences are taken into account when purchasing a hairdryer and that it took several iterations of purchases before adequate hairdryers were found. The model we evaluated was comfortable to use and did not require bending of the wrist. Unfortunately, the model was not well-suited for left-hand use; interestingly, the stylists reported that there were currently no left-handed employees.

The flat iron did not allow the user to maintain a straight wrist and put pressure into the palm of the hand. The clipper did not have these problems. Both the flat iron and clipper contained pinching hazards.

5. Discussion

5.1 Limitations of the study

The current study was an analysis of operations in a single salon during one day of measurement. This provided rich qualitative data and allowed us to examine the task, organizational, and personal levels. However, any issues found in the current sample are not immediately generalizable to all cosmetologists. A broader study would benefit from a survey of all employees at a salon, or a sample of salons in the United States.

As mentioned earlier, the literature review suggested consideration of airflow and ventilation within the salon. Although our observations and survey data did not detect major problems, future studies should include a direct measurement of the air quality. There were no self-reported issues with respect to inhalation of fumes from mixing chemicals or applying colors and aerosol sprays. However, it was later suggested that the stylists might already be accustomed to the air quality, and that some long-term risk might be prevalent.

5.2 Conclusions

The prevalence of serious injuries at this particular salon was low, but our analysis revealed a moderate level of risk for injury over the long-term. This is in agreement with the literature, which describes injuries that develop over an extended period of time.

We found moderate levels of CTD risk for most of the stylists. The correlation analysis had similar results. Work experience was significantly correlated with pain in neck and shoulders, and frequency of hand cutting was correlated with pre-existing CTD conditions. These results do not imply that one causes the other, but are relevant topics for future investigation.

The analysis of hand tools and workplace stations reveal moderate risk as well. The hand tools included in this analysis do not give any indication of severe risk with respect to long term palm, finger, or wrist injury. At the same time, these tools do not exhibit any extreme qualities of ergonomic design, such as form fitted grips or angled handles.

With the exception of the hair cutting stations, the workplace was characterized by rigid, non-adjustable, surfaces. Most tools were within a reasonable reach at each workstation, except at the mixing lab. The mixing station had floor to ceiling shelves, and little floor space to maneuver for reaching these items. One participant found the sink too high and had to lean over to reach the faucet.

Employees also agreed that the floors throughout the entire salon were too hard to walk or stand on continuously. The use of anti-skid/ pressure dampening floor mats could be one ergonomic solution.

Clearly, the task and environmental factors might indicate that there should be a higher incidence of injury within this particular salon. One reason for low incidence of injury may have been individual differences and/or personal factors. Individual interviews with the stylists and staff reveal awareness of comfort and safety. For example, with respect to hairdryers, the manager reported that "we've gone through many different brands before agreeing on this one." When asked about scissor design, stylists reported that there are many different types of scissors, depending upon the type of cut to be performed, and that it is not unusual for a stylist to have multiple pairs of scissors to accomplish this task. For example, stylists can have scissors with rounded tips to prevent hand cuts, while also having a pointed pair for precision cutting.

At the organizational level, we noted that personal health was discussed at the employee meetings. Topics included safe working postures, stretching during work, and breaking throughout the day for rest. Additionally, all employees reported participation in at least one athletic activity outside of work.

In this salon, however, stylists balanced performance and safety. The manager remarked that, although they would certainly be willing to purchase a more ergonomically designed hair dryer, for example, the stylists would rather have tools and work in an environment which allowed them to do great work first. Safety, therefore, was sometimes a secondary consideration.

Hairstylists may be willing to risk injurious behavior in order to garner a good reputation as a talented stylist and thereby retain a strong customer base. Certainly, this is important to one's success in the industry, but sacrificing safe practices risks the worker's health. In the salon environment, stylists must maintain an awareness of their long-term well-being, while also attending to the immediacy of the task. Examinations of other professions where creative or quality work is important, such as cooking or welding, may reveal similar ergonomic concerns.

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Valuation of Advanced Manufacturing System Investments Using Real Options Approach

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Abstract

The traditional discounted cash flow (DCF) analysis is not suitable for evaluating advanced manufacturing system investments since it ignores the flexibility to revise the original decisions. In this paper, a real options approach is presented to overcome the limitations of conventional DCF models by incorporating option values of flexibilities to defer, to change scale, and to abandon the investment for salvage while evaluating an advanced manufacturing system investment. The proposed valuation framework is based on binomial lattices and risk-neutral analysis. An illustrative example is presented, and sensitivity analyses are conducted.

1. Introduction

The effects of globalization have compelled the manufacturing firms to ensure cost efficiency and effectiveness while lowering the costs. Manufacturing flexibility forms a significant part of a firm's competitive strength and is considered among the dimensions of a firm's competitive strategy along with price, quality, and dependability [4].

The advances in computer technologies and integration of systems with the use of robotics and material handling systems gave birth to advanced manufacturing systems (AMS). An AMS provides several tangible and intangible benefits, however it may result in substantial financial burden on the company.

The evaluation of AMS investments has been in the research agenda for two decades. Investment justification methods for advanced manufacturing technologies such as group technology, flexible manufacturing systems (FMSs), industrial robots, etc. are classified into economic analysis techniques, analytical methods, and strategic approaches [13]. Unfortunately abovementioned techniques are short of evaluating both strategic and financial aspects of AMS investments simultaneously.

Recently, there is a consensus among the investment science experts that investment models require strategic and financial considerations to be reconciled and integrated. The valuation of real-life option situations can be performed with the advancements in options theory and the enhancement in the valuation of a wide range of complex options. Hence, options approach appears here as a means of overcoming the restrictions posed by ordinary DCF methods and improving the decision-making process of a qualitative evaluation.

If future opportunities depend on today's decisions, there exists a time-series link between projects [14]. For example, in a two-stage investment project where the second stage depends on the justification of the first, forecasting the cash flow profile for both stages and applying a standard DCF method such as net present value (NPV) analysis would not provide the correct result since the second stage is an option and DCF techniques are not appropriate for valuing options. While making the decision to invest in the first stage of the project, the management buys a call option on the second stage. Options approach deviates from the conventional DCF approach in that it views future investment opportunities as rights without obligations to take some action in the future [3]. The asymmetry in the options expands the NPV to include a premium beyond the conventional NPV calculation. Thus, properly accounting for the value of flexibility could increase the total value of the project and the probability of justification.

A number of researchers have addressed the option value of flexibility in manufacturing. Kulatilaka [9] analyzed the value of flexibility using a stochastic dynamic programming model. Triantis and Hodder [16] developed a model for valuing a flexible production system with an option to switch its product mix over time. Kumar [11] proposed a method of valuing expansion flexibility based on options theory. Karsak [6] presented an approach for valuing expansion flexibility and product flexibility in FMSs using exchange options. Karsak and Özogul [7, 8] proposed an analytic approximation methodology for valuing sequential American exchange options on dividend paying stocks to value expansion flexibility in FMS investments.

The purpose of this paper is to propose a real options-based valuation methodology that enables decision-makers to evaluate and justify AMS investments incorporating multiple interactive options. The option valuation model developed in this study extends the binomial lattice framework to model an AMS investment opportunity. The rest of the paper is organized as follows. Section 2 provides a concise treatment of flexibility types in AMS investments, and section 3 introduces background material on real options. In section 4, a real options-based framework for evaluating AMS investments is developed. In section 5, a comprehensive numerical example is presented to illustrate the approach, and in the following section sensitivity analyses are conducted. Finally, section 7 presents concluding remarks.

2. Flexibility in AMS investments

Possessing the agility to respond to changes in market conditions appears as a key to success in technology-based manufacturing. Flexibility can be defined as the ability of the system to respond to changes quickly and economically. Flexibility in manufacturing processes provides an ability of changing or even reversing the decisions made in earlier periods. The value of flexibility increases with uncertainty, and flexibility has no value when there is no uncertainty [15].

For instance, an FMS contains flexibility related to future capacity or 'action flexibility' in the terminology of Mandelbaum [12] since it is an integration of separate centers that can be added or removed from the system depending on the future demand for the product. Azzone and Bertelè [1] defined routing flexibility, process flexibility, product flexibility, production flexibility, volume flexibility and expansion flexibility as elementary types of flexibility considering that they can be measured by indicators that are mutually independent. Positive correlation and potential overlaps are generally present among these types of flexibility. Hence, firms must determine the types of flexibility that are of highest concern to their competitive advantage.

This paper focuses on deferral flexibility, expansion flexibility and flexibility to abandon the investment for salvage, and their proper consideration in evaluating AMS investments. Deferral flexibility can be defined as the value of waiting before an investment takes place, thereby giving the opportunity to take advantages of future information. Expansion flexibility can be defined as the ability to easily add capability and capacity to the existing system. A major strategic advantage of expansion flexibility is that it avoids the large financial commitment at a single time point and provides the ability to invest incrementally according to the changes in demand. This advantage enables the firm to minimize its financial burden by limiting significant up-front cash outflows. Expansion flexibility allows for phased-expansion in production, rather than acquisition of all equipment at the initial investment stage. A firm could start with adequate capacity to provide minimum efficient production, and then invest in additional capacity as markets expand and demand increases. This also leads to more knowledgeable decisions compared to initial investment stage as better market information is acquired through time. Flexibility to abandon for salvage can be defined as abandoning the investment project permanently due to severely worsening market conditions in order that project resources could be sold or put to alternative uses.

3. Real options

An option is the right, but not the obligation, to buy or sell a particular asset at a specified price on or before a certain expiration date. The buyer of an option may choose to exercise his right and take a position in the underlying asset while the option seller, also known as the option writer, is contractually obligated to take the opposite position in the underlying asset if the buyer exercises his right. The price at which the buyer of an option may buy or sell the underlying asset is the exercise price.

An American option can be exercised at any time prior to expiration, while a European option allows exercise only on its expiration date.

While financial options are options on financial assets such as stocks, bonds, foreign currencies, and precious metals, real options (RO) are opportunities on real assets that can provide management with valuable operating flexibility and strategic adaptability. Analogous to financial options, real options enable their owners to revise future investment and operating decisions according to the market conditions. Real options technique does not only value the managerial flexibility through the investment horizon, but it also supports and expands the firm's strategic frame [10]. Nevertheless real options technique should not be seen as a substitute for the traditional DCF methods. On the contrary, these methods should be considered as complementary to each other. In other words, traditional or passive NPV should be seen as indispensable and necessary input to option-based analysis to determine extended NPV (ENPV) which can be calculated as

$$Extended\ NPV = Passive\ NPV + Value\ of\ options$$

Real options valuation approach has the potential to conceptualize and even quantify the value of operating flexibility and strategic adaptability. This value expresses the real options embedded in the investment opportunities. Many of these real options occur naturally such as options to defer, shut down or abandon, while others may be planned and built-in at some extra cost such as option to expand. A classification of widely encountered real options can be found in Trigeorgis [17].

Advanced technology investments create opportunities for manufacturing firms to invest or divest in subsequent time periods based on the realized market conditions. A substantial part of the market value of companies operating in volatile and unpredictable industries such as electronics, telecommunications and biotechnology can be attributed to the real options that they possess [3]. Since real options preclude the traditional passive analysis of investments and imply active management approach with an ability to respond to changing conditions, advanced manufacturing investments prove to be a suitable application area for real options approach. In other words, real options approach enables manufacturing firms with the required insight to assess opportunities and act on them before they become obvious to other firms in the market.

4. Reel options framework for valuing AMS investments

This section addresses the value of common managerial and strategic flexibilities that an AMS investment could possess. A generalized road map illustrating how to apply real option framework is detailed below in order to provide a comprehensive insight of the RO-based evaluation technique.

The first step of the valuation framework is to determine model variables and parameters. Since passive NPV is a component of the RO analysis, the formulation of the traditional NPV model is required. In light of managerial and strategic flexibilities embedded in the AMS investment, we proceed by mapping them to the appropriate real option type while considering the interactions among them. A typical AMS investment generally hosts investment traits implying respective operating options: option to defer, option to expand, and option to abandon for salvage.

Having isolated flexibilities inherent in the project, the next step is to evaluate these options. There are a number of techniques developed by researchers for valuing options. These techniques can be categorized into three main groups: analytic solution techniques, analytic approximations, and numerical procedures [5].

Analytic solution methods provide a certain solution for option valuation considering some partial equilibrium constraints to prevent arbitrage opportunities. Analytic solution methods are the easiest and the most widely used techniques for valuing options; however, they are of limited use in valuing options with complicated payoffs. Analytic approximations are derived for cases where analytic solutions cannot be determined. Numerical procedures are useful when analytic solutions or analytic approximations are not applicable. Numerical procedures can be used to value options when exact formulas are not available. Binomial lattices, finite difference methods, and Monte Carlo simulation can be listed among the numerical procedures. The computations in binomial lattices and finite difference methods work backward from the end of the life of the option to the beginning whereas Monte Carlo simulation works forward. Binomial trees and finite difference methods are preferred when early exercise opportunities exist. Monte Carlo simulation is particularly useful for the valuation of options where the payoff is dependent on the history of the underlying variable or where the number of underlying variables is more than three [5]. Among numerical procedures, lattice models offer more modeling flexibilities and are capable to evaluate both European and American type options.

The decision to select a numerical procedure among the ones mentioned above depends on the characteristics of the option being evaluated and the accuracy required. Typical AMS investments can incorporate multiple interactive options, and thus, binomial lattice models appear to be much more convenient as they provide a more comprehensive class of solutions. A model based on binomial lattices is apt to capture the contingencies of real options and addresses almost all of the common criticisms of employing option theory to manage those contingencies [2].

In the next step, the evaluation model is formulated. Providing modeling flexibilities, lattice method is preferred compared with other evaluation techniques. Hence, this step essentially requires the construction of the price tree reflecting possible values of the underlying asset and forming the evaluation trees which express specific traits of the AMS investments. Once the model is built and the basic investment case is evaluated, next step requires the generation of different scenarios reflecting possible market conditions. The results of the extended NPV analysis are interpreted to offer a thorough road map to the decision-maker. Thus, a decision support tool designed to maximize the value of an AMS investment is made available to the decision-maker for planning specific operating options.

5. Illustrative example

In this section, we consider a manufacturing firm analyzing an AMS investment proposal. The company acquires the right to defer initial investment, and then make an expansion investment if favorable conditions occur, and abandon AMS investment for salvage value if unattractive business conditions are present.

The base case parameters and the expected basic components used in the valuation of

AMS investment are given in Table 1 and Table 2, respectively.

Table 1. Base case parameter values

Parameter	Value
Initial investment cost (I_0)	\$2,000,000
Initial product price ($P_{0,0}$)	\$15
Product price volatility (σ)	20%
Risk free rate of return (r_f)	5%
Inflation rate (r_e)	3%
Rate of return shortfall (δ)	3%
Length of the deferral period (T_D)	2 years
Number of sub-periods In T_D years (N_D)	24
Length of the production period (T_P)	8 years
Number of sub-periods in T_P years (N_P)	96
Expansion investment cost (I_E)	\$300,000
Expansion rate (x)	25%
Salvage value (I_S)	\$700,000
Lower bound / Upper bound for product price (P_L / P_U)	(\$5 / \$45)

First of all, the project is evaluated employing the conventional NPV method. Using base case parameter values given in Table 1 and annual production rate and operating expense figures denoted in Table 2, passive NPV can be calculated as follows:

$$NPV = \sum_{i=1}^{T_p}\left(\frac{P_{0,0}\cdot \text{ProdRate}(i) - \text{OpExp}(i)}{\left(\left(1+\frac{r_f+r_e}{12}\right)^{12}\right)^{i}}\right) - I_0$$

Discounted present values of benefits and costs of the AMS investment yield -\$121,427, a negative NPV, and thus, the project should not be justified using conventional NPV analysis.

As noted in the proposed real options based valuation framework, the flexibilities inherent in the project are acknowledged and the real options types to model these flexibilities have been determined. After this mapping process, it is seen that prospective AMS investment hosts the following options simultaneously: option to defer, option to expand, and option to abandon for salvage.

Table 2. Annual production rate and operating expense figures

Year	Production rate	Operating expenses
1	90,000	\$800,000
2	85,000	\$800,000
3	80,000	\$800,000
4	75,000	\$800,000
5	70,000	\$800,000
6	65,000	\$800,000
7	60,000	\$800,000
8	55,000	\$800,000

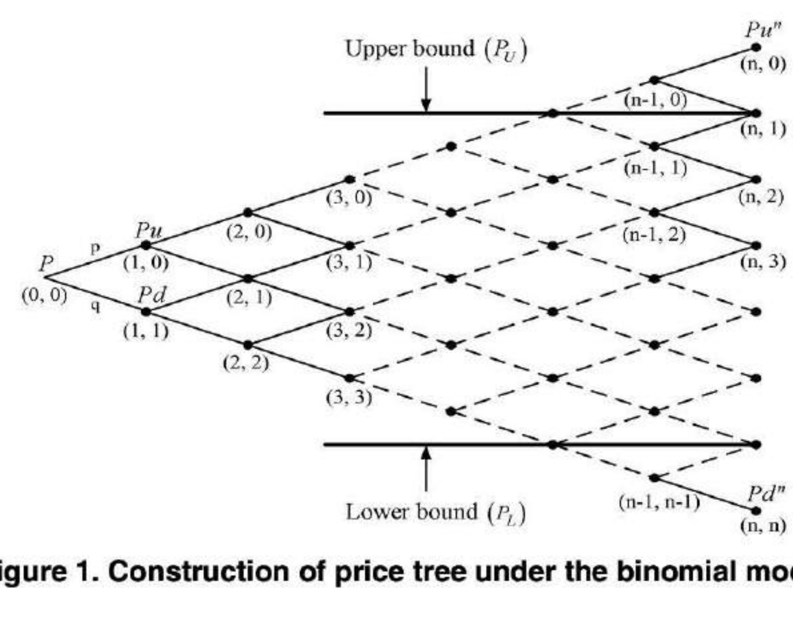

Figure 1. Construction of price tree under the binomial model

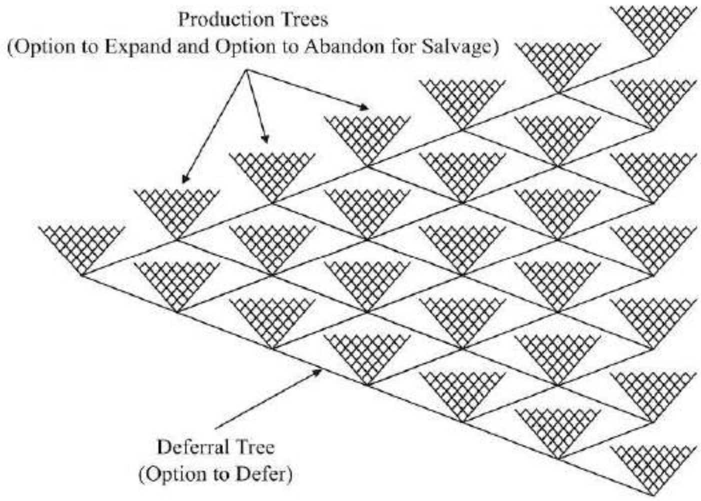

Figure 2. Tree used to value AMS investment

The real options valuation model employs binomial trees due to their modeling advantages and flexibilities they include for valuing American-type options and for calculating compound option values. The next step requires the construction of the price tree and valuation trees as depicted in Figure 1.

$P_{i,j}$ is the product price at the ith stage and jth state for the binomial model and is defined as follows:

$$P_{i,j} = \begin{cases} P_L, & if\ P_{0,0}u^i d^{i-j} \le P_L \\ P_H, & if\ P_{0,0}u^i d^{i-j} \ge P_H \\ P_{0,0}u^i d^{i-j}, & if\ P_L < P_{0,0}u^i d^{i-j} < P_H \end{cases}$$

where $P_{0,0}$ denotes initial value of $P_{i,j}$, i is the stage variable (i = 0,1,.., n), j is the state variable (j = 0,1,…, i), n is the total number of sub-periods in binomial lattice ($n = N_D + N_P$), u is the upward movement multiplier ($u = e^{\sigma\sqrt{dt}}$), and d is downward movement multiplier ($d = e^{-\sigma\sqrt{dt}}$). The probability of upward movement p is expressed as $p = \frac{e^{(r_f-\delta)dt} - d}{u - d}$, while q denotes the probability of downward movement, where $q = 1 - p$.

Table 3. ENPVs and option values for individual and combined real options

Real option type	ENPV ($)	Option value†
Defer	858,447	979,874
Expand	805,376	926,803
Abandon	1,046,709	1,168,136
Defer&Expand	1,101,301	1,222,728
Defer&Abandon	1,187,340	1,308,767
Expand&Abandon	1,169,648	1,291,075
Defer&Expand&Abandon	1,310,649	1,432,076

† Option value = ENPV – Passive NPV

After calculating basic model values and price tree, binomial trees have been constructed in the following step to value deferral, expansion, and abandon for salvage options. As depicted in Figure 2, the basic structure of the proposed valuation framework is based on two different binomial trees. The vertical binomial tree, which we name as production tree, values the expansion and abandon for salvage options. The horizontal binomial tree, which we name as deferral tree, computes the combined value of deferral, expansion and abandon for salvage options using the results from the production tree in a way that enables to take into account the option interactions. Extended NPVs (ENPVs) and options values for individual and combined real options are denoted in Table 3. As shown in Table 3, the value of an option in the presence of other options differs from its value in isolation.

6. Discussion

In this section, various scenarios are generated considering changes in model variables and parameters in order to both calculate how possible changes in market conditions may affect the project's cash flows and study the interactions among the options inherent in the project. Then, the results of the sensitivity analyses are interpreted. Thus a road map is provided to the decision-maker for optimizing their medium and long-term strategies considering the AMS investment.

Table 4 provides the range of parameter values used in the scenarios. The computed ENPV figures for the parameter values given in Table 4 range from \$591,156 to \$1,919,499, and they all justify the investment due to the inherent option values.

Table 4. Parameter values for sensitivity analysis

T_D	1 year	2 year	3 year		
σ	10%	15%	20%	25%	30%
r_f	4%	5%	6%		
δ	2%	3%	4%		

As depicted in Figure 3, the risk-free rate, r_f, and the length of the deferral period, T_D, have synergistic effect on the ENPV. Furthermore, the increase in T_D, which implies possible increase in the product price, makes the decision to wait for better market conditions much more significant.

As shown in Figure 4, the increase in the length of the deferral period, T_D, reflecting the value of waiting for more favorable conditions, creates positive effect on the ENPV. On the other hand, rate of return shortfall, δ, indicating opportunity cost of delaying the AMS investment decreases the option value. One shall note that higher δ values, which approximate perfect competition, pose deeper impact on the ENPV.

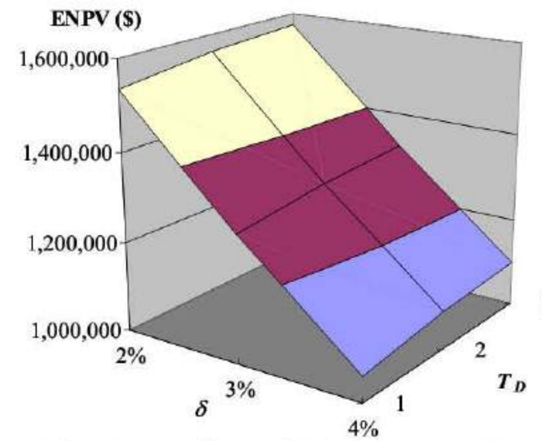

Figure 4. Effect of δ and T_D on ENPV

Finally, the effect of σ and T_D on the ENPV is presented in Figure 5. In real options context standard deviation, σ, signifies the uncertainty which exists in the named investment opportunity. Operating options inherent in AMS investment amplify the positive-side of the uncertainty, and thus, increase the ENPV of the AMS investment. Similar to standard deviation, the length of the deferral period, T_D, contributes positively to the ENPV of the AMS investment.

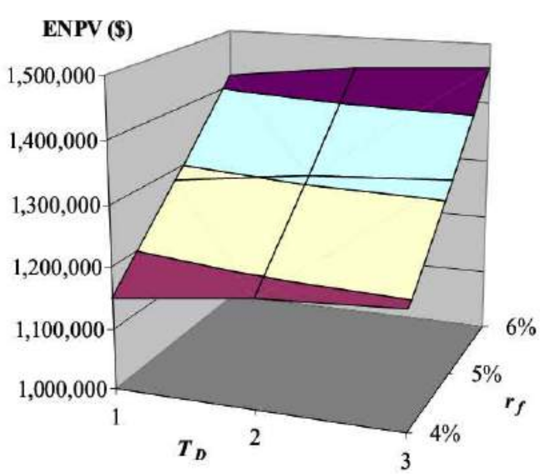

Figure 3. Effect of r_f and T_D on ENPV

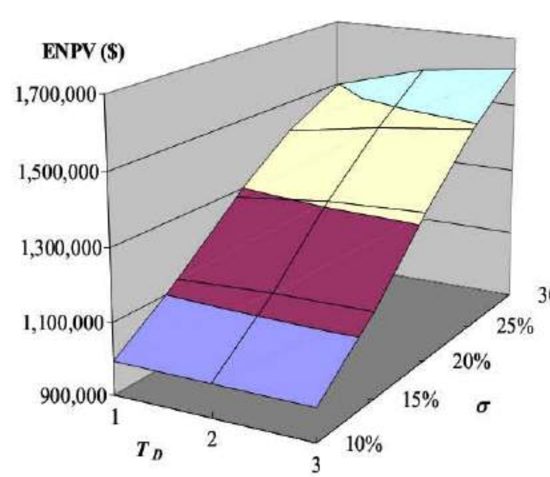

Figure 5. Effect of σ and T_D on ENPV

7. Concluding remarks

This paper extends the previous works on the application of real options approach to advanced manufacturing system investments. The real options literature has given little attention to the fact that real-world advanced manufacturing system investments usually incorporate multiple interacting options. This study introduces a real options based methodology that enables decision-makers to value an AMS system investment incorporating multiple options.

This study shows that even an investment that is not justified using traditional valuation methods, can be valuable for a firm and its shareholders considering the strategic and managerial flexibilities inherent in the investment, and with the effect of favorable market conditions in the future.

Further, the results indicate that the value of an option in the presence of other options differs from its value in isolation. When there exist multiple real options, option interactions should be properly taken into account since simply adding the option values will in general mislead the decision-maker by overstating the project value.

The options perspective outlined in this study is a critical first step in establishing a clear linkage between many traits of AMS investments and their business value. Since an AMS investment requires substantial capital expenses, it is necessary to effectively align the business strategies with the financial strategy and the manufacturing firm's objectives. While option values may be difficult to quantify in certain cases, undertaking an investment analysis using a real options analysis framework will help managers to focus on and account for major factors that affect the value of the project.

Applying the proposed real options-based valuation methodology to other advanced manufacturing system investment projects, which may embed additional flexibilities to the ones considered in this paper, will be the subject of future research. Furthermore, empirical studies are encouraged to gain more insight into the assumptions made concerning the stochastic processes and into their validity.

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