Decision Support System by using Tunable Simulation for Optimally Mixed Systems

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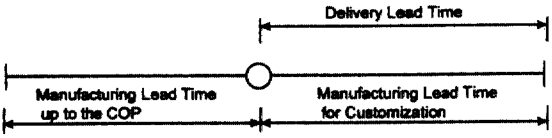
〈Abstract〉

The mixed push and pull production system defines that all stages are not ordered by either of the production systems. Some stages are ordered by a push-type production system and the other stages are ordered by a pull-type production system. A decision support system is built by using a combination of optimization program and the "tunable" SIMAN discrete-event simulation for the implementation of an optimally mixed production system. Finding this optimal system requires 6 CPU hours for the case study on a Pentium. Both the simulation and optimization model are validated with a case study of Phoenix company that manufactures transmitters. This paper uses survey from experts in this company for evaluation and validation of this system.

1. Introduction

Customer order point (COP) is defined as the point in the manufacturing process at which the product is assigned to a customer order as shown in 〈Figure 1〉. For example, in the make-to-stock (MTS) case the COP is at the finished goods' inventory, and in the make-to-order (MTO) case the COP is at the raw material inventory. The delivery lead time is then the time from the COP to delivery. An integration of push and pull systems at the COP implies that one part of the lead time is pushed and the other part is pulled [4].



〈Figure 1〉 Customer order point (adapted from [5])

As shown in 〈Figure 2〉, COP is the ordering point from the customer's point of view and junction point (JP) is a transition point from the manufacturer's point of view. JP is defined as the last push station in horizontally integrated hybrid push and pull production system which the first several stations are push (MTS) and remaining are pull (MTO).

A single JP in the production line marks a transition from the push to pull systems. This mixed production system can handle any type of manufacturing environments that are MTO, assemble-to-order (ATO), and MTS, if the transition point (junction point) can be adjustable that starts to assemble the final products according to the actual customer demand. Manufacturers can produce any type of products by using this

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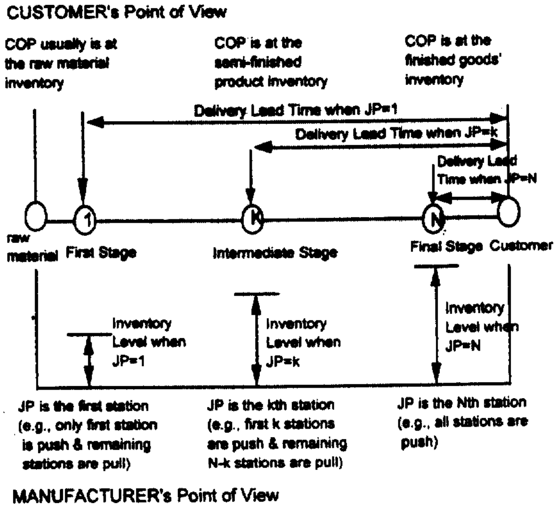
system. This is an important point in this paper; that is, the existence of an movable JP between the push and pull segments of the system.

As shown in 〈Figure 2〉, the location of a JP can be decided depending on the user's manufacturing strategy. For example, the inventory level (IL) is getting higher if the JP is close to the last station because the total IL of the push (MTS) system portion is getting higher (more forecasting error and queue of each push station) with relative high rate. On the other hand, the manufacturer can reduce the delivery time to customer. Therefore, if the unit IL cost is much lower than the unit delivery lead time (DLT) cost, the manufacturer would prefer the mixed system of which push (MTS) is a major portion (i. e., JP is close to the last station). On the contrary, if the JP is close to the first station, the total IL is getting lower because the pull (MTO) system portion keeps the inventory level low. On the other hand, the delivery time to customer is getting longer. Because more manufacturing lead time (MLT) is required, with waiting time at each pull station, it takes more time to go from the first pull station (JP+1) to the last station to make the final products. Therefore, if the unit DLT cost is much lower than the unit IL cost, the manufacturer would prefer the mixed system of which the pull (MTO) is a major portion (i.e., JP is close to the first station). If the semi-finished product (SFP) is not available (shortage of SFP) at the output buffer inventory of the last push station when the first pull station requests the SFP, the DLT should include the reorder lead time that it takes to refill the SFP. If the safety stock of SFP is large enough, we can reduce the possibility of a shortage and total IL should be increased. Otherwise, the possibility of shortage is increased and DLT should be increased. Also, if the number of kanbans in pull portion is large enough, there will be no delay in making final products from SFP. Otherwise, MLT of the pull portion is usually getting longer, which means that the DLT will be longer. Thus, in this mixed system, the location of the JP and safety stock of SFP in push, and the number of kanbans in pull potion will be the issues to control the IL and DLT. There is a trade-off between DLT and IL based on these decision variables [1].



〈Figure 2〉 Trade-off between IL and DLT with JP

In this paper, we describe the tunable simulation and decision support system for optimally mixed system.

2. Software design for optimally mixed system

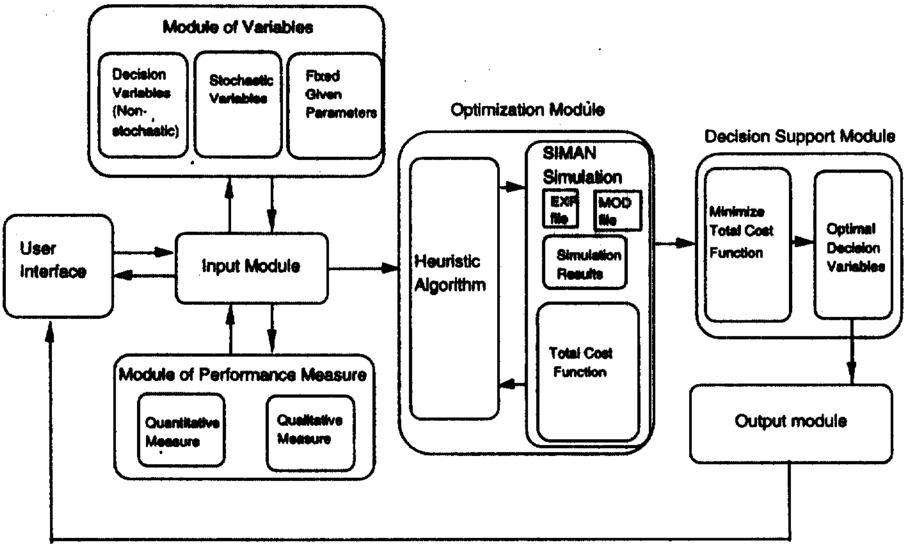
Section 2.1 describes the design of decision support system for optimally mixed systems. The SIMAN tunable simulation model is described in section 2.2.

2.1. Decision support system

This section describes the decision support system for the optimally mixed push and pull production system. This system consists of seven modules as shown in 〈Figure 3〉. The modules are user interface, input, output, variable, performance, optimization, and decision support modules.

Input module has interaction with users and two modules (modules of variables and performance measures). User can decide the important independent (decision) and dependent variables. User can key in and change the variables and performance measures through this module.

The module of independent variables consists of controllable decision variables, stochastic (uncontrollable) variables, and fixed given parameters.



〈Figure 3〉 SIMAN tunable simulation and decision support system

The module of performance measures is for the dependent variables. These can be quantitative or qualitative. Cochran and Kim (1996) use the location of JP, safety stock of semi-finished products, and number of kanbans as decision variables. They used average waiting time for each pull station and average queue size for each push station as uncontrollable stochastic variables. These come from the simulation. They used the number of stations, average processing time of each station, average customer demand, and unit costs as given fixed variables. Also, they used inventory level and delivery lead time as performance measures.

The module of optimization consists of optimization program and simulation. They used a heuristic algorithm and SIMAN simulation model. This simulation model consists of experimental and model files. These files in the simulation can be created based on information from customer through the input module. In other words, the C++ program [3] creates model and experimental files based on user's input information. This module also creates the objective function (total cost function), which is based on simulation results obtained from the variables and performance measures.

The decision support module keeps the total cost values with different combination of local optimal decision variables allowing the user to select the manufacturing setting conditions.

Output module is a result of optimization and tunable simulation, which have been defined by the user's selection of any combination of decision variables with minimum total cost value.

2.2. Tunable simulation model

The main point of tunable simulation model is that JP is movable and adjustable for manufacturing conditions. For example, JP can be station 1, station k, or station N based on manufacturer's strategy as shown in 〈Figure 2〉. The tunable SIMAN simulation model consists of adjustable push and pull system portion.

The push system portion represents the traditional queuing model approach. Incoming raw materials are sequentially processed through the JP, which is the last push station. The throughput time in the push system portion represents the push processing time plus any queuing at the push machine stations.

In the pull system portion, completed parts from each machine are placed in a kanban inventory or queue. This kanban inventory must initially be loaded with the desired inventories. Incoming customers' orders are entered a queue for the kanban cards. Incoming orders are matched with available kanban inventory. If a match is possible the order is immediately filled by transferring the part to customer. This transaction triggers an order for the part processed by the last station. Again, a match between queues for the kanban cards and for the parts in queue is attempted. When a match becomes possible, the part is sent to the last station for processing, and an order is sent to station number (last station-1). This cycle is repeated backwards through the pull system portion. The JP is movable and adjustable for manufacturing conditions in the model [5, 6].

3. Analysis of mixed production system for real case study

Section 3.1 gives the description of product and production process of the case study. Section 3.2 describes the model definition of the case study and classification of variables. Section 3.3 analyzes the comparison between the "as is" and "to be" systems.

3.1. Description of product and production process

Phoenix company makes Series 100/600 transmitters. The manufacturing conditions for each station are shown in ⟨Table 1⟩ The transmitters send signalized information about chemical process pressures to receivers. The clients for their product line are large petroleum companies. There is a very high implied cost of being late for delivery in terms of future contracts and present penalties. On the other hand, as electronic components are involved, there are also moderate inventory costs.

Notice that there are 16 major manufacturing steps in the system as shown in ⟨Table 1⟩ A pure push approach is being used now. Management is interested in evaluating the potential

⟨Table 1⟩ Production process and processing time for each stage

Operation ID	S100/600 Operation	# of servers	Operation Time/100 transmitters	Total Time for each process	Operation Time/1 lot (17 transmitters)
1.1 or 6.1	1st Sensor Weld	1	3.067	3.067	0.510
1.2 or 6.2	Adaptor Weld	1	2.108	2.108	0.350
1.3 or 6.3	2nd Sensor Weld	1	3.067	3.067	0.510
1.4 or 6.4	Fill Meter Body	2	8.146	8.146	1.357
1.6 or 6.6	Steam Clean	1	0.767	0.767	0.127
1.7 or 6.7	FSPM	1	4.217	4.217	0.700
1.8 or 6.8	Rook Weld	1	2.108	2.108	0.350
1.9 or 6.9	Load Drying Oven		0.359		
1.9 or 6.9	Unload Drying Oven		0.359		
1.9 or 6.9	Pot Adaptor	1	1.821	3.257	0.540
1.9 or 6.9	Load Curing Oven		0.359		
1.9 or 6.9	Unload Curing Oven		0.359		
1.10 or 6.10	Load RTS & Start	1	1.989	2.468	0.410
1.10 or 6.10	Unload RTS		0.479		
1.11 or 6.11	Load ETS & Start	1	2.276	3.025	0.500
1.11 or 6.11	Unload ETS		0.749		
1.12 or 6.12	Program PROM	1	1.438	1.438	0.240
1.13 or 6.13	Load CV Oven	1	0.579	3.280	0.540
1.13 or 6.13	Unload CV Oven		2.701		
1.14 or 6.14	Plugs to Heads	1	0.096	0.096	0.016
1.15 or 6.15	Build	1	3.833	3.833	0.638
1.16 or 6.16	Rough Cal.	1	3.833	3.833	0.638
1.17 or 6.17	Cal.	1	4.153	4.153	0.690
Total			48.86	48.86	8.116

cost savings from moving to a pull philosophy and is open to the idea of potentially saving even more money by making only a partial move from push to pull.

3.2. Model definition and variables

The followings are the manufacturing conditions and the variables of the simulation model for the real case study.

Manufacturing conditions

- The production line is not balanced.
- First-come, first-served is used throughout the study.
- The ratio of costs is very high at 20 (unit DLT cost) to 1 (unit IL cost).
- A straight line topology (no subassembly) is studied (16 stations in the serial line).

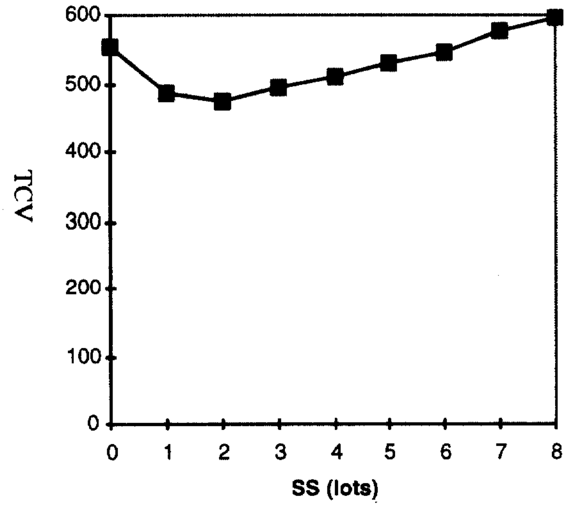
Parameter of the simulation model

- The unit IL cost includes the opportunity cost, space cost to stock, and maintaining cost. The unit DLT cost (lateness cost) includes the credit of the company, customer satisfaction (if the delivery is delayed, the customer may not accept the final products), and market share (there is the possibility losing the customers if the delivery is delayed). We used unit DLT cost (20,000 \$/day) with fixed unit IL (1000 \$/lot).
- There are 16 stations in this case study. Any station can be a JP in this system. There is only one server at each station except station 4. There are two servers at station 4.
- In the simulation of this case study, the mean inter-arrival time of raw material is 4 days, which is log-normally distributed and the coefficient of variance (CV) is 0.5.
- The production time at each station is different, as shown in ⟨Table 1⟩ The processing time at each station is log-normally distributed with a different mean processing time.
- The batch sizes of the push and pull station are 6 lots and 2 lots, respectively.
- The number of kanbans for each pull station is assumed to be the same.
- The manufacturers accept the customer order by lot. The inter-arrival time of a customer order is exponentially distributed with mean 0.6 days. We assume that customer demand follows a Poisson distribution with a mean of 2 lots.

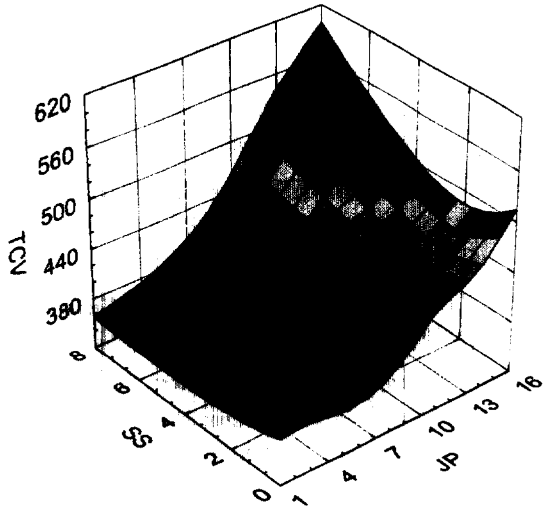
3.3. Comparison between current and proposed production system

⟨Figure 4⟩ shows a summary of two sets of runs of the model. The "as is" production system of the Phoenix transmitter company is pure push. Therefore, in terms of the model, JP is 16 (the last station). Controlling the safety stock of final products is the only policy that this company can explore using this model within a pure push system. ⟨Figure 4⟩ (a) shows the total cost value (TCV) as a function of the last station safety stock (SS). The manufacturers of our Phoenix company want to improve the performance from the current pure push system. ⟨Figure 4⟩ (b) shows the TCV of a model of the proposed system with all possible combinations of JP and the most interesting values of safety stock in which the number of kanbans is two (NK*=2).

Cochran and Kim (96) made several recommendations to our transmitter manufacturer. First, the simulation model alone



(a) Current "as is" system



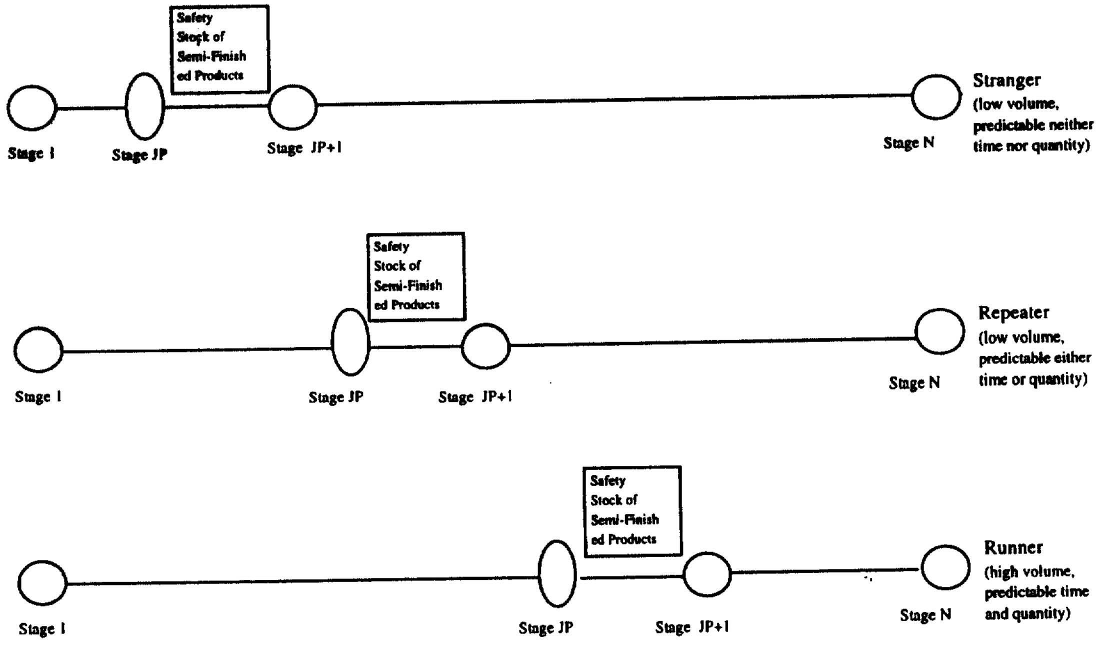
(b) Proposed "to be" system when NK*=2

〈Figure 4〉 Case study results of Phoenix transmitter company

shows that inventory and throughput improvements are possible by traditional bottleneck elimination. Second, they can save roughly 20-25% of their total late costs and inventory costs. This range of solutions is allowable because the surface is fairly flat in the optimal region for this system and some JP's make more sense than others in terms of the nature of the semi-finished product there. Third, if they wish to stay with the current all-push configuration, maintain 2 lots of finished product at the end of the production line. This will give you some insurance against unexpected customer demands.

3.4. Inference from case study

It is necessary to define certain terms to have the inference from the case study. There are several kinds of products in this company, which are called Runner, Repeater, and Stranger. Runners are the products for which the customer amount and time of need are predictable. These products are high volume and high standardization. Repeaters are the products for which either the customer amount or the time of need are predictable. Strangers are the products for which neither customer amount nor time of need are predictable. These products are low volume and low standardization. The mixed push and pull system that has more portion of the first MTS is suitable for Runner. The mixed system that has a greater portion of the



〈Figure 5〉 Inference for All Product Cases last MTO is suitable for Stranger as shown in 〈Figure 5〉. The location of the JP, safety stock of SFP and number of kanbans for pull stations must be decided, depending on the types of products. Ideally, three different types of products need different production lines and different combinations of decision variables. The mixed system with a tunable JP can handle any type of products under different production environment.

4. Evaluation of the case study

The evaluation of the case study has been performed by experts and actual users in a Phoenix company. Answering the questions, the evaluators evaluate the performance of the proposed system and its effectiveness.

4.1. Questionnaires for validation

The performance criteria were translated into questionnaires (survey type). The questionnaire consists of two major sections with a total of fifteen short questions. Part one contains questions evaluating the concept. Part two contains eight questions related to the case study itself. There are many ways to represent the qualitative measures to quantitative scales. The most popularly and commonly used technique is to use a discrete evaluation scale. The evaluation criteria are pre-scaled, and the evaluator responds to each question with one of the predetermined scales. A numeric value is assigned to the individual indicators. All questions require the participant to respond on a ten-point scale from 0 (very strongly disagree) to 10 (very strongly agree), with 5 being "neither disagree nor agree".

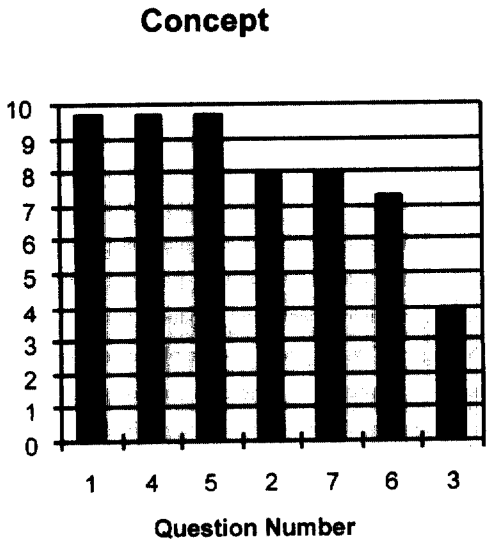
4.2. Analysis of results

〈Figure 6〉 and 〈Figure 7〉 show the ranks of the average scores. The 〈Table 2〉 is the summary for these results.

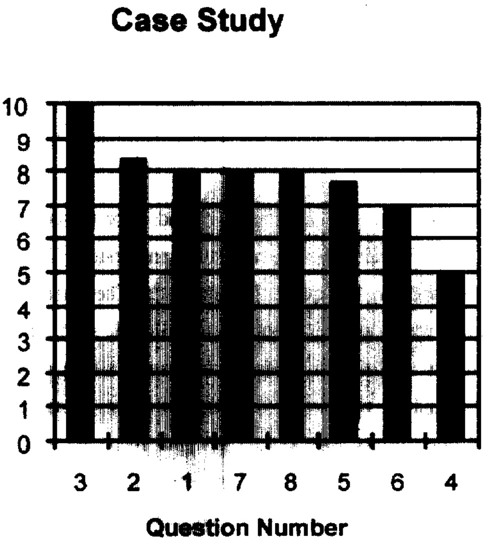
The evaluators strongly agree on questions 1, 4, and 5 for the concept and 3 for the case study. They need a tool to help their organization decide whether a push or pull approach is needed. They think that an HIHPS planning tool would be useful to their company. They strongly agree that the case study model captures a fundamental tradeoff they face in their organization.

They agree on the questions 2, 6, and 7 for the concept and 1, 2, 5, 6, 7, and 8 for the case study and results. They prefer the approach to the qualitative approach. They need more a complete study of their system using HIHPS. Also, they think a commercial software product based on this type of analysis would find a market. It means that they agree that the simulation results of the current and proposed system are reasonable. Also, they agree that the optimization results of the current and proposed system are reasonable. Thus, the "as is" and "to be" systems are validated.

They moderately agree on question 3 for the concept and question 4 for the case study and results. The average score of this question is relatively low because they have used the terms, push or pull, for a long time. But, they are still confusing the definition of push, pull, make-to-order, and make-to-stock. They do not have much time to collect the data that they need to analyze their systems



〈Figure 6〉 Average score (ranked) of the questions for the concept



〈Figure 7〉 Average score (ranked) of the questions for the case study and results

〈Table 2〉 Summary table for the evaluation of the current and proposed systems

	Range of average scores	Question number for concept	Question number for case study & results
Strongly validate	9-10	1, 4, and 5	3
Validate	7-8	2, 6, and 7	1, 2, 5, 6, 7, and 8
Moderate validate	4-6	3	4

5. Conclusion

Tunable simulation and decision support system are developed to decide the optimally mixed system for specific company. This system with movable junction point can control the total inventory level and delivery lead time under any type of production environments and products (Runner, Repeater, and Stranger). This system are implemented for Phoenix company and evaluated by experts in this company. They need a tool to help their organization decide whether a push, pull or mixed approach is needed. They strongly agree that the case study model captures a fundamental trade-off they face in their organization. The enabling technology for this system must be developed for the future work.

[Reference]

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김성수

1996년부터 현재까지 한국통신 멀티미디어 연구소 물류 시스템 개발팀에서 선임연구원으로 재직 중이며 삼성전자에서도 2년간 근무한 경력이 있다. 한양대학교에서 공학사(1986), 미국 일리노이 대학교에서 공학석사(1988), 위스콘신 대학교에서 수학하였고, 아리조나 주립대학교에서 산업공학박사(1996)를 취득하였다. 주요 관심분야는 CIM, 생산 시스템 분석 및 최적화 설계, 물류 정보시스템 구축 및 관리, 지능형물류교통시스템 등이다.

97년 4월 최초 접수, 97년 7월 최종 수정