Benchmarking: An International Journal

Managing span of control efficiency and effectiveness: a case study

Raed El-Khalil Abdul-Nasser El-Kassar

Managing span of control efficiency and effectiveness: a case study

Raed El-Khalil and Abdul-Nasser El-Kassar
Department of Information Technology and Operations Management, Lebanese American University, Beirut, Lebanon

Received 28 April 2014
Revised 20 March 2015
Accepted 21 March 2015

Abstract

Purpose – The purpose of this paper is to address the following issues: first, the significance of the three independent variables (the chassis, trim, and assembly departments) on the three outputs (direct run loss first time capability, jobs per hour (JPH) lost, and injury rate); second, the optimal level of span of control based on the best achieved outputs; and third, whether increasing the span of control post 2009 improved manufacturing outputs in comparison with a span of control pre 2009.

Design/methodology/approach – The optimal level of span of control at the automotive Big Three (Chrysler LLC, Ford, General Motors) is investigated using design of experiments.

Findings – The analysis shows that the variables are significant for all outputs, except for chassis on injury. All three variables deteriorate as the span of control increases. The paper indicates that the lower the span of control the better the output variables.

Originality/value – Based on the recommendations given by the managers at the Big Three facilities visited, the top three variables that were utilized from the assembly facilities for this study are the span of control at the Chassis, Trim, and Assembly departments, and the outputs are Direct Run Loss First Time Capability, JPH Lost, and Injury Rate.

Keywords Efficiency, Automotive industry, Direct run loss, Injury rate, Jobs per hour lost, Span of control

Paper type Case study

1. Introduction

Driven by globalization and the fall of the Soviet Union, the 1990s witnessed growth of new markets which led to the exposure of domestic companies in North America to fierce foreign competition, especially in the automotive field. The Big Three companies (Chrysler LLC, Ford, and General Motors) responded by investing in technologies that can result in efficiency improvements. According to Nevins *et al.* (2003), the most imperative elements for increasing efficiency are creating and implementing innovations in the technical and organizational areas of a firm. Tools such as proper machines buffers, manufacturing flexibility, and product mix can also support efficiency improvement (Geismar *et al.*, 2011; Kouvelis and Tian, 2013; Kouvelis and Li, 2009).

The 2009 economical crises caused a significant decline in the automotive market shares which, according to the Research and Statistics Branch at the United Nations Industrial Development Organization (2010), forced the Big Three to make major organizational changes. Post 2009, special attention was given to the span of control and its efficiency and effectiveness within the firms (Wunker, 2012). According to Neilson and Wulf (2012), managers work toward a "magic number" to determine the optimal number

The author would like to thank the *Benchmarking: An International Journal* reviewers for their support. Special thanks are extended to the Editor-in-Chief, Professor Angappa Gunasekaran. The author would also like to thank the Big Three management and personnel for their support and contribution for this research.

Benchmarking: An International Journal
Vol. 23 No. 7, 2016
pp. 1717-1735

1463-5771
DOI 10.1108/BIJ-04-2014-0037

for an efficient and effective span of control. Even though each company may require an individual analysis to determine that optimal number, Hopej and Martan (2006) believe that determining that number for a span is an endless process. Moreover, an important issue discussed by Hopej and Martan (2006), Wunker (2012), and Kawai (2011), is wide and narrow span of control and its impact on organizational performance. Management theorists suggested widening spans of control to gain efficiencies (McConnell, 2000). Orlando *et al.* (2006) also argue in favor of a wide span of control indicating "that a higher proportion of managers are indicative of structures with a narrow span of control, and vice versa." Other scholars, though, state that the increased interaction between supervisors and operators of the narrow span of control leads to improved performance (Gittell, 2001).

According to Wunker (2012), the Big Three's new trends are based on downsizing and flattening the organizations. Herein, labor unions in the automotive industry (i.e. United Auto Workers "UAW") negotiate with institutions to protect the rights of employees (El-Khalil, 2009). Even though labor unions may positively enhance firm performance by encouraging employee cooperation, complying with the demands of the UAW may also negatively affect firm performance by pressuring it into more effort and expense (Tsai and Shih, 2012).

This paper examines the impact of increasing span of control at the Big Three automotive companies in North America post 2009 financial crises on several productivity outcomes that were recommended by those companies (i.e. injury rate, jobs per hour (JPH) lost, and direct run first time (DRFTC)). The research was driven by a request from one of the Big Three, and its main objective is to determine the significance of the input variables (i.e. span of control at each department) on the output variables (i.e. injury rate, JPH lost, and DRFTC). The paper also explores the level of deterioration and/or improvement that took place pre and post 2009 in regards to output variables, and provides recommendations on how to improve these variables. The data used was obtained from 50 UAW facilities at the Big Three (with a labor force ranging between 2,500 and 2,800 employees), and was analyzed using Minitab.

2. Background: automotive assembly facility

The manufacturing assembly process within the automotive facilities is designed in a sequential pattern. This process is known as a continuous flow or referred to as a line flow, as illustrated in Figure 1. The automotive facility is comprised of three main departments, and each department is divided into several sections or zones. The sequences or departments are as follows:

- Stage 1 is the body shop department (Body in White (BIW)) which is divided into seven to nine sections. Stamping parts come to the facility from the stamping plant and are welded together in order to form the shell of the vehicles. This department is highly automated as most of the work is done by welding robots.

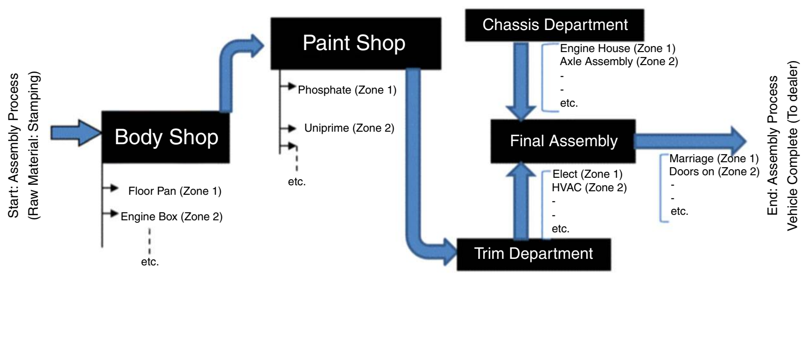

Figure 1.
Automotive facility: manufacturing and assembly process layout

- Stage 2 is the paint shop which is divided into six to seven zones. After the body shop constructs the shell, it is shipped to the paint shop where it is washed, coated, and painted. This department is less mechanical than the body shop department.
- Stage 3 is the assembly stage which is divided into three departments: chassis, trim, and final. Each department contains five to seven zones. At the trim department, installation of the interior parts (e.g. wires, HVAC, and carpet) takes place. At the chassis department, installation of underbody parts (e.g. axle, engine, prop shaft, fuel tank) occurs. At the final assembly, the marriage of the trim to chassis portions takes place, in addition to the installation of other parts (e.g. wheels, doors, moldings).
- The last zone in the final assembly is dedicated to inspecting and road testing. If vehicles pass through this process with no problems, they are sent to parking lots in order to be shipped to dealers. If problems occur during inspection and road testing, vehicles are repaired and tested again. If they fail, they will be scraped and/or disassembled for parts resale.

2.1 Assembly facility layout: departments and zones

The design of the process layout in the manufacturing facility directly affects the efficiency and utilization of a company (El-Khalil and Halawi, 2012). The objective of any process layout is to organize the company's physical facility in a manner that promotes an efficient use of people, equipment, material, and energy (Dolgui and Proth, 2010). All the automotive assembly process layouts contain the following main departments: BIW, paint, and assembly departments (discussed above). In general, the BIW contains the following zones, in sequential order:

- engine box;
- front and rear floor;
- 3 underbody subassembly;
- floor line;
- underbody 1 and 2;
- apertures assembly: right and left;
- frame line;
- closer line: doors (right and left, back and front); and
- panel line.

The paint department is divided into the following zones, in sequential order:

- sand deck and sealer;
- phosphate and E-coat;
- powder;
- color booth 1 and 2;
- polish deck and black out deck; and
- final inspection and repair.

The final department is divided into five zones, as illustrated in Figure 2. The last zone (inspection and road testing) is divided into six different inspection stations. Each of these six stations will perform different types of test on every vehicle. If a problem is detected, the vehicle will be repaired and tested again (in each test stage). Most vehicles will proceed to the next stage, but if they are rejected "again," they will be disassembled and/or scraped.

2.2 Organizational structure: span of control and responsibilities
The standard organizational structure at the automotive manufacturing facilities is comprised of several levels, as illustrated in Figure 3. A typical facility organizational chart could have up to five different levels. This is shown in Table I.

According to Wilson (2010), empowerment at all levels will result in higher productivity. Encouraging employees to make decisions and giving them greater influence tend to benefit both the employees and the employers (Liker, 1998). For this reason, how employees express their interests, solve problems, participate in their work, and make decisions are important issues. Kim *et al.* (2010) refer to Levine and Tyson (1990) and state that typically there are two ways for employees to address their concerns: team voice and representative voice. Team voice is a direct relation between employees and management. Employees tend to have a direct influence on management which happens through employee involvement programs (Kim *et al.*, 2010). A representative voice is an indirect form of employee influence. The indirect forms occur via workers' representatives (i.e. union, work councils, employee representatives, etc.)

All of the Big Three automotive facilities' workers (skilled and non-skilled) in North America are part of the UAW. All employees are indirectly participated (i.e. representative voice). The UAW is the labor union representing the workforce in the facilities. Its main objective is to embody their workforce in negotiations with management in order to insure proper and fair worker contracts. In addition, UAW representatives (facility steward) at the facility work on resolving conflicts with management at all levels with all their employees, including production supervisors. It is important to note that within the Big Three, each type of employee "group" is given a specific classification that is agreed upon during UAW/management negotiation. The higher the classification, the more skills the job requires and thus more monetary

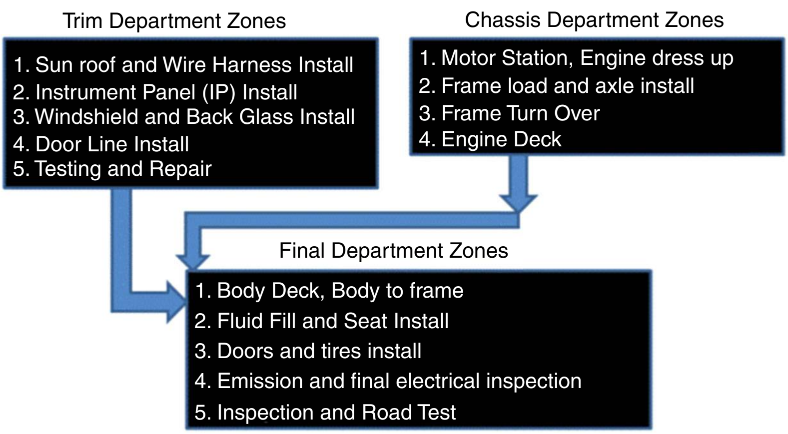

Figure 2. Assembly department: process layout by department and zone

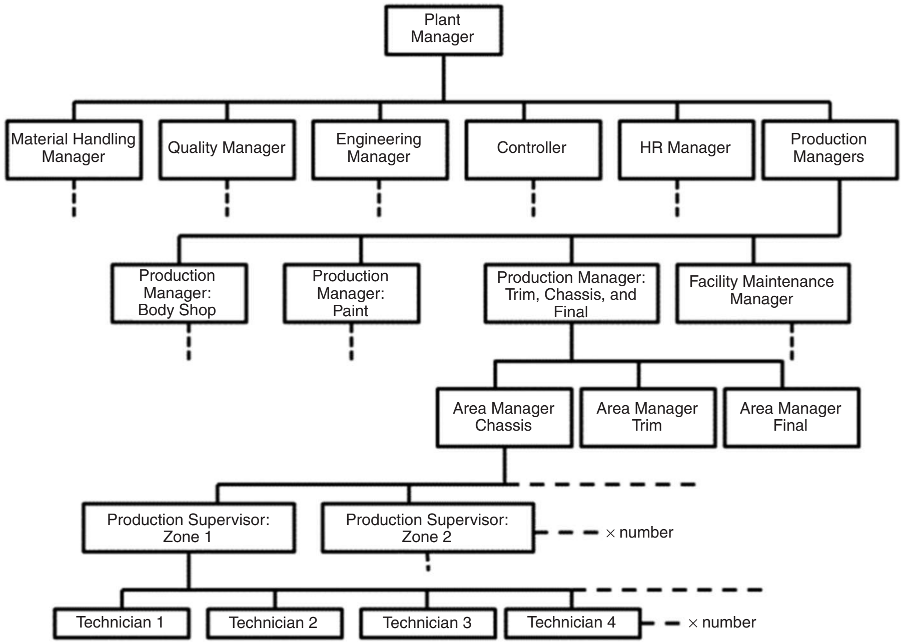

Figure 3. Manufacturing facility organizational structure

allowance is given. For example, a team leader and/or inspector are given a classification that is different and requires more effort than a line worker or a technician. Therefore a small team, organized of a technician, skill trade, union Steward, supervisor, manager, and an engineer is established. This team concept will ensure that employees function properly in the production process, share common tasks, and support each other to achieve common goals. Also, the team concept will enhance the workers' right to voice their opinions and suggest changes. Kim *et al.* (2010) found that neither team voice nor the representative voice shows a significant relationship toward labor productivity when solely observed. However, team voice, considered in concurrence with representative voice, significantly enhances worker efficiency.

2.3 Business plan and scorecard

The automotive assembly facilities operate based on a business plan that is created by all employees within the facility. The business plan is updated annually and includes scorecard targets for safety, quality, delivery, cost, moral, and environment (SQDCME). These targets are detailed and tracked on daily bases by facility managers and employees. The purpose of establishing a business plan system is to deliver business success that is driven by discipline in development and execution (El-Khalil, 2015). Based on the facilities visited, this process:

- Is developed with all levels of the organization.
- Establishes one common goal and alignment to focus on established objectives. These objectives support the scorecard process: SQDCME goals and objectives.

Level	Title	Requirements and description
1	Technicians	Paid hourly Responsible for a defined work area Given a specific work load to be performed within takt time Notify production supervisor in case issues arise that prevent operation completion
	Line workers or skilled trades	Paid hourly Perform work based on need Perform scheduled maintenance Respond to problems that arise during production Notify production supervisor in case issues arise that prevent operation completion
2	Production supervisors	Ensure their zone/department employees deliver production requirements within takt time, at the required quality, and at a given cost Train employees and plan for production Assign technicians to work station Direct and adjust workloads Appraise employee performance, reward, and discipline employees Address complaints and resolves problems Adjust tools and machines Ensure technician efficiency and work load is assigned properly Conduct Scorecard review Orders and obtain material required for technicians Assist and support technicians in solving work problems Translate targets and plans (given by upper management) to their subordinates
3	Engineering and engineering managers	Ensure that machine and equipment throughout the facility perform work according to specifications Focus on implementing plans to support scorecard objectives and resolve any problem that might cause operation stoppage Support production supervisors in achieving short- and long-term facility objectives
4	Functional managers (maintenance and area managers, facility engineers; controller office, HR, material handling, and quality personnel)	Require full understanding of every aspect of the operation Responsible to resolve problems that arise in their departments and support other groups to achieve facility goals Directly linked to the production supervisor
5	Facility upper management (i.e. facility, HR, quality, controller, material handling, and production managers)	Require understanding of all technical functions Set scorecard objectives Establish a process/plan in order to achieve them Monitor the process of implementation Create alternative to ensure achievement of objectives

Table I.
Organizational levels and descriptions

- Provides a plan that gives focus and direction.
- Drives continuous improvement process.

The score cards are divided into several items. For example under safety, there are several measures that the safety department focusses on. These measures include: injury (fatal and non-fatal), lost work days, permanent disability, temporary disability, and others.

For each of the safety measures, the department will establish a current state and implement goals that focus on reducing and/or eliminating problems case by case.

Based on the recommendations given by managers and engineers at the facilities visited through this research, the three most important variables that we need to focus on (that directly impact cost) are the following:

- Quality: DRFTC that measures build in quality for the facility. The number is measured in the last zone of the final line department.
- JPH lost: measures the amount of vehicles lost vs forecasted due to technician issues.
- Safety (non-fatal): measures injuries at the facility driven by problems within the facility premises that cause injuries to employees.

The above three issues among others are measures that the business plan tracks on a daily basis. Those issues are part of a process that identify problems and implement solutions to improve the facility's overall performance.

Quality capability: DRFTC. The automotive companies (i.e. Big Three) utilize DRFTC in order to evaluate the capability of building quality in the process and to clarify the problems to be resolved. The DRLFTC is a standardized method of measurement that is common through all facilities at the Big Three. DRLFTC, also known as FTC is measured by multiplying throughputs from the six stages/stations in the inspection zone (final department), as illustrated in Figure 4. As presented in Figure 4, the first stage in the process shows that out of the 1,000 vehicles which were introduced in stage 1, 150 vehicles were detected for repair out of which 120 vehicles were reintroduced (re-run) in the system. The losses at stage 1 were 30 vehicles and the DRLFTC for stage 1 was 85 percent. Similar calculations will be applied through the six stages in the inspection zone and all the numbers will be multiplied in order to calculate an overall DRLFTC for the inspection zone, as illustrated in Figure 4.

It is the responsibility of the production supervisor to identify the root cause of each job lost in his or her zone and trace it back to its roots. The production supervisors through the facility will support the identification of the root cause of those issues discovered at the inspection station and drive each issue to its effected station in order to resolve it with their production teams.

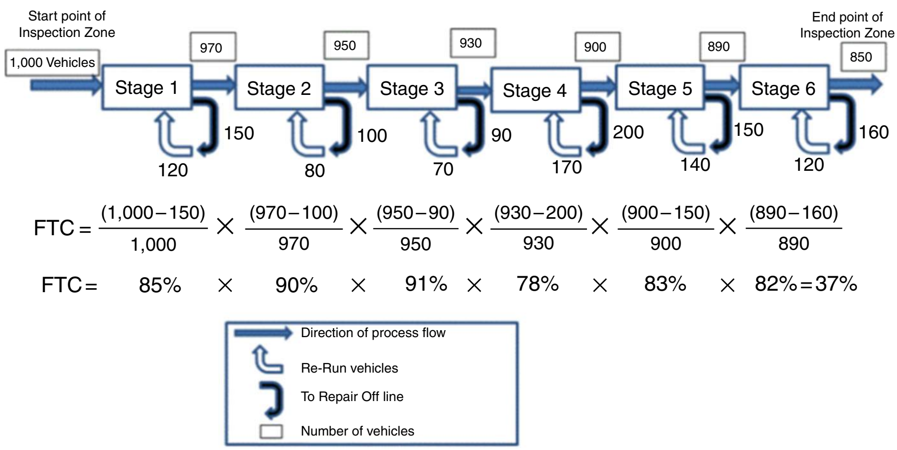

Figure 4.
Calculating DRLFTC by stage (final department)

JPH (lost). The JPH lost is a number calculated at the facilities to reflect lost production volume caused by operator-related issues. These issues include items found during production that cause line stoppage. Examples of such issues are: misassembled parts, missing parts, and wrong parts installed.

$$\text{JPH(lost)} = \text{JPH} - \text{down time(unpredicted down time)}$$

where:

$$\text{JPH} = \frac{\text{Time available per hour for prodcution}}{\text{Time it take to produce a vehicle}}$$

- Time available per hour for production = one hour – forecasted down time (i.e. breaks, lunch, team meetings, and/or maintenance).
- Time taken to produce a vehicle is determined by takt time. The latter is determined annually by the forecasted sales (the takt time is calculated by dividing available annual working days by the annual forecasted volume of production).

The production supervisor is required to review each job per hour lost within his or her department and zone (with the production employee) and conduct a practical problem-solving process that reviews the issue, finds the point of origin, identifies the root cause, creates countermeasure, and insures long-term solution feasibility. In short, he or she ought to create a robust solution for the problems in order to prevent reoccurrence.

Injury (non-fatal). The safety department within each facility tracks injury-related issues (fatal and non-fatal). The injuries (non-fatal) are based on the incidence rate which represents the number of injuries and illnesses per 100 full-time workers and were calculated as:

$$\text{Injury : non fatal(incidence rate)} = \frac{N}{EH} \times 200,000 \text{ hours}$$

where N is the number of injuries and illnesses, EH the total hours worked by all employees during the calendar year and 200,000 the base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

This type of injury is defined by US Department of Labor (2011) as "a serious injury or illness that may render the service member medically unfit to perform the duties of the member's office, grade, rank, or rating." Each automotive company included in this research is required to submit this information on an annual basis to the US Department of Labor. Within each department and zone, part of the production supervisor's duties is to perform safety checks and review all injuries occurring within his/her area and implement countermeasures that prevent reoccurrence.

Labor efficiency. Labor efficiency is determined based on the operation work sequence performed by each operator within a specified work period. Operation work sequence is the sequence of steps followed by the operator in order to accomplish the required task. The objective of this step is to list and detail each task with the time required to conduct it. Time associated with each task has to be identified in one of the two categories: value added or non-value added work and or task based on the definition of each as illustrated in Figure 5. This information will be critical for calculating efficiency of each operator and/or efficiency of each department.

The calculation for efficiency is determined by the following equation:

$$\text{Operation efficiency} = \frac{\text{Operation cycle time}}{\text{Line cycle time}}$$

2.4 Hypothesis formulated

Since the main objective of the study is to determine the significance of the three independent variables (i.e. chassis $= x_1$, trim $= x_2$, and assembly $= x_3$) on the three outputs determined, the following hypothesis is formulated:

H1. The three independent variables have no significant impact on the outputs determined (i.e. DRFTC, JPH lost, and injury rate).

3. Methodology

3.1 Research design

The study is quantitative for the results were measured numerically and analyzed using specialized statistical software packages. Moreover, the paper is a combination of both a descriptive and explanatory nature. It describes the optimal level of span of control based on the best achieved outputs. An explanatory study, however, is more emphasized since the research establishes a causal relationship between the span of control at the chassis, trim, and assembly departments, and the outputs DRFTC, JPH lost, and injury rate. It tests the existence of a relationship between increasing the span of control and improving manufacturing outputs. The research is longitudinal since it involved a study for over a period of five years. It is an extension of an earlier study that was presented at the 24th Production and Operations Management Society Conference in Denver, USA (El-Khalil, 2013).

The following was required to proceed with the study:

(1) Establish a list of comparable facility. The list was verified with facility managers to determine the nature product, process, and technology used. The focus was to insure that the facilities studied have identical process.

(2) Utilize a survey that is given to the facilities managers and which determines:
- assembly departments to focus on (input variables); and
- top three output variables to focus on.

(3) Study each facility and establish a list of all its input and output data.

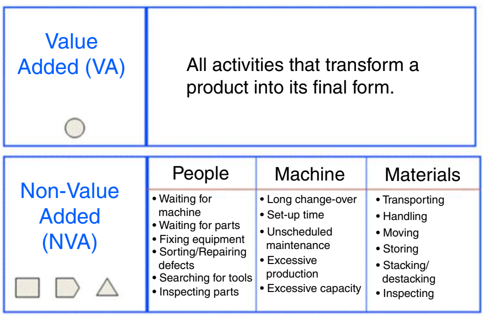

Figure 5. Value added and non-value added tasks

(4) Establish input combination, based on the DOE, and determine if all combinations are available in the list. If not, drop identical input combination and study other facilities that have the required combinations. This step was the most consuming one because it involved visiting more facilities that might or might not have the required combinations.

(5) Input data and run DOE analysis.

(6) Determine results and conduct interviews with facility managers in order to verify and obtain managers' inputs on results.

3.2 Sample and experiment

The Big Three companies were contacted and asked for permission in order to visit their facilities and interview personnel for this research. After discussing the paper's objective with senior managers, the companies provided a list of facilities with specific dates for benchmarking visits. The following are some of the characteristics of the facilities studied:

(1) They produce one of three different types of vehicle segments (Sedan, Minivans, and Sport Utility Vehicle "SUV").

(2) All departments are identical from a process perspective.

(3) Line cycle time for all facilities is similar (1 min $\pm$ 13 sec).

(4) Technology and tools utilized by technicians are identical.

(5) All facilities studied operate under a team work grouping. Each team utilize five to six people who rotate on different jobs every two hours within the same group.

All interviews and visits were conducted between November 2010 and May 2013.

Designs of experiment were utilized in this paper to design, conduct, and analyze the experiment in order to effectively draw an objective decision and or conclusion. The experiment was a full factorial design (three factors at levels 3), $3^3 = 27$. Independent variable codes are: −1 "low," 0 "average," and 1 "high" (where low = 50, average = 81, and high = 110). The factors are: C = chassis (x_1), T = trim (x_2), and A = assembly (x_3).

The data presented in Figure 6 is a sample of the information obtained from 32 different automotive assembly facilities at the Big Three in North America. The survey asked how many departments the facilities had. It also questioned the level of span of control, the direct run loss, the given JPH, and the number of non-fatal injuries of the facility before and after 2009. The supervisors were also asked if they had a say in the number of people they supervise, and if they are satisfied with the processes and changes from pre to post 2009, such as the increase in the span of control. Moreover, how much time is spent on average per week with each employee, besides the regular team meetings was inquired.

The data shows an average number for three years data prior to 2009 (2007, 2008, and 2009) and one average number for four years post 2009 (2010, 2011, 2012, and 2013). A sample of the data obtained from the different facilities and the different combinations for the experimental run which was used is presented in Figure 6.

The outputs utilized based on recommendations by the facilities are:

Output 1: DRFTC.

Output 2: JPH lost.

Output 3: injury (INJ).

Manufacturing Facility Data

Facility 1

Span of Control			Direct Run Loss			Jobs Per Hour			Injury (non-fatal)		
Department	Pre-2009	Post-2009		Pre-2009	Post-2009		Pre-2009	Post-2009		Pre-2009	Post-2009
Body	22	35	DRL	63%	65%	JPH	1.8	1.1	Lost Work Days	3.1%	2.8%
Paint	30	42									
Chassis	25	50									
Trim	30	50									
Assembly	35	50									

Facility 2

Span Of Control			Direct Run Loss			Jobs Per Hour			Injury (non-fatal)		
Department	Pre-2009	Post-2009		Pre-2009	Post-2009		Pre-2009	Post-2009		Pre-2009	Post-2009
Body	30	42	DRL	59%	55%	JPH	3.2	3.8	Lost Work Days	3.3%	3.7%
Paint	25	50									
Chassis	35	90									
Trim	35	90									
Assembly	25	90									

Figure 6.
Sample of data obtain for the doe (study by facility)

Therefore, three designs of experiments combinations were performed:

$$DR = a_1 \times C^{k_1} \times T^{L_1} \times A^{m_1}$$

$$JH = a_2 \times C^{k_2} \times T^{L_2} \times A^{m_2}$$

$$INJ = a_3 \times C^{k_3} \times T^{L_3} \times A^{m_3}$$

Take the natural log of the above three equations:

$$Ln\, DR = Ln\, a_1 + K_1 Ln\, C + L_1\, Ln\, T + m_1 LnA$$

$$\text{Ln}\, JH = \text{Ln}\, a_2 + K_2 \text{Ln}\, C + L_2\, \text{Ln T} + m_2 \text{Ln}A$$

$$\text{Ln}\, INJ = \text{Ln}\, a_3 + K_3 \text{Ln}\, C + L_3\, \text{Ln T} + m_3 \text{Ln}A$$

The quadratic models for the outputs are as follows.

For DR:

$$y_1 = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3$$

For JN:

$$y_2 = c_0 + c_1x_1 + c_2x_2 + c_3x_3 + c_{11}x_1^2 + c_{22}x_2^2 + cx_3^2 + c_{12}x_1x_2 + c_{13}x_1x_3 + c_{23}x_2x_3$$

For INJ:

$$y_3 = d_0 + d_1x_1 + d_2x_2 + d_3x_3 + dx_1^2 + d_{22}x_2^2 + d_{33}x_3^2 + d_{12}x_1x_2 + d_{13}x_1x_3 + d_{23}x_2x_3$$

4. Analysis of results

The outputs obtained from the Minitab software, presented in Tables II-IV, show the following:

- All p-values based on analysis of variance is less than 0.05, which is a clear indication to reject the hypothesis. In other words, it means that there is a

5 percent probability (maximum) that the results are randomly distributed. The result indicates that the term *C* (chassis), *T* (trim), and *A* (assembly) are significant for all responses of output except for *C* on INJ since its *p*-value of 0.064 is greater than 0.05 as illustrated in Tables II-IV.

- Based on the main effects plots (Figure 7) we conclude that DRFTC, JPH lost, and injury deteriorate as the span of control increase. This deterioration is more significant in trim and assembly departments.
- Interaction plots in Figure 8 indicate that there are interactions for JPH lost: chassis and trim at average and high levels, and chassis and assembly at high levels. For DRLFTC, there are interactions between chassis and trim, as well as between chassis and final at average levels. JPH lost also shows similar results to DRLFTC. Overall, the interaction plot shows that as span of control increase, interaction tends to increase.
- The presented plots clearly indicate that the lower the span of control, the better is the three outputs.

Generally, the span of control has a direct impact on the three variables. This impact increases as the span of control increases.

Table II. Analysis of variance for DRLFTC, using adjusted SS for tests

Source	DF	Seq. SS	Adj. SS	Adj. MS	*F*	*p*
x_1:*C*	2	0.0096519	0.0096519	0.0048259	9.69	0.001
x_2:*T*	2	0.0041185	0.0041185	0.0020593	4.13	0.031
x_3:*A*	2	0.0107630	0.0107630	0.0053815	10.80	0.001
Error	20	0.0099630	0.0099630	0.0004981		
Total	26	0.0344963				

Table III. Analysis of variance for JPH lost, using adjusted SS for tests

Source	DF	Seq. SS	Adj. SS	Adj. MS	*F*	*p*
x_1:*C*	2	4.8052	4.8052	2.4026	9.15	0.002
x_2:*T*	2	4.5163	4.5163	2.2581	8.6	0.002
x_3:*A*	2	2.3030	2.3030	1.1515	4.39	0.026
Error	20	5.2519	5.2519	0.2626		
Total	26	16.8763				

Table IV. Analysis of variance for INJ lost, using adjusted SS for tests

Source	DF	Seq. SS	Adj. SS	Adj. MS	*F*	*p*
x_1:*C*	2	0.0002196	0.0002196	0.0001098	3.16	0.064
x_2:*T*	2	0.0005287	0.0005287	0.0002643	7.62	0.003
x_3:a	2	0.0007242	0.0007242	0.0003621	10.43	0.001
Error	20	0.0006942	0.0006942	0.0000347		
Total	26	0.0021667				

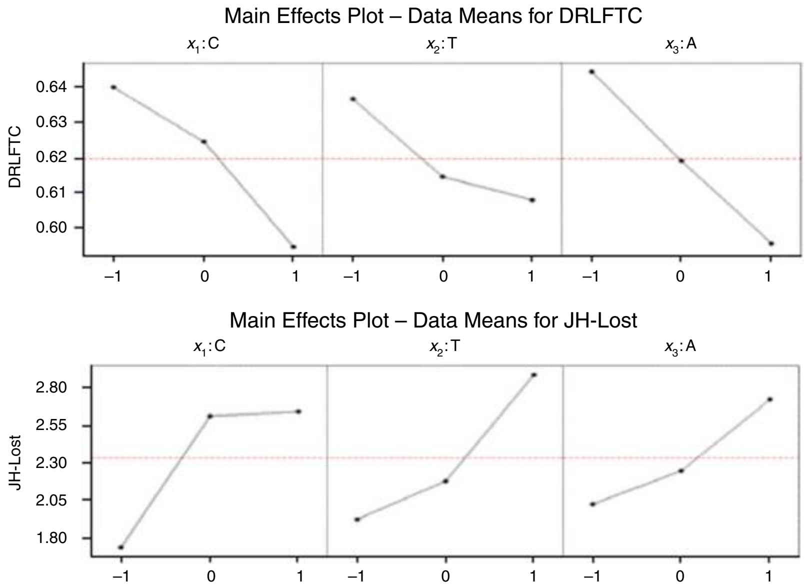

Figure 7. Main effect: sample plots for DRFTC and JPH lost

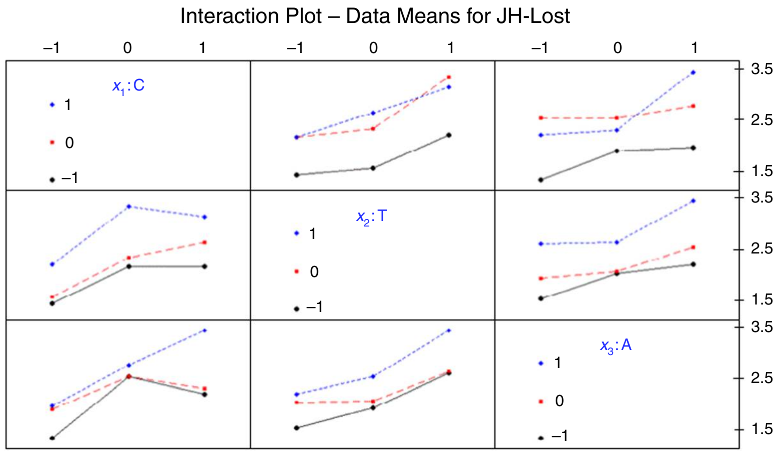

Figure 8. Interaction plot: sample for DRLFTC and JPH lost

4.1 Increasing span of control post 2009

The span of control at all the North American automotive companies increased after 2009. The level of changes (i.e. increase, decrease) in outputs and inputs varied significantly, as illustrated in the manufacturing facility data in Table V. At its lowest level, the increase was 67 percent and at its highest level the increase went up as high as 271 percent as illustrated in Table V and Figure 9.

In comparison with data from pre 2009, the post 2009 numbers indicate the following:

- Increase in the span of control by 170 percent.
- Deterioration in DRLFTC by an average of 2 percent.

- Deterioration in JPH lost by an average of 3 percent.
- Deterioration in injury rate by an average of 29 percent.
- The increase in the span of control from pre 2009 to post 2009 was not a standard increase. Some facilities increased by 67 percent (lowest increase) and others by 271 percent (highest increase).
- The facilities which had the lowest number of increase in most cases (seven facilities) showed an improvement in all three outputs.

In its attempt to support the supervisor's new task, the automotive companies (Big Three) adopted the Toyota Production System of span of control. This new adopted concept introduced an additional level to the management process which is a technician team leader as illustrated in Figure 10. The technician team leader is an employee selected from the same zone or department, and his or her task is to help support team members in conducting their task. Part of the team leader's task is to:

- insure that all technicians' machine and or equipment are available and running to specification;
- support technician in case problems occur;

Table V. Pre vs post 2009: output and input changes

	Span of control (%)	DRLFTC[a] (%)	JPH-lost[b] (%)	Injury[c] (%)
Min.	67	−14	−52	−25
Max.	271	11	45	164
Average	170	−2	3	29
Std	55	6	25	38

Notes: Calculated % = (Post 2009-Pre 2009)/Pre 2009×100. [a]DRLFTC: positive = deterioration and negative improvement; [b]JPH lost: positive = deterioration and negative improvement; [c]injury positive = deterioration and negative improvement

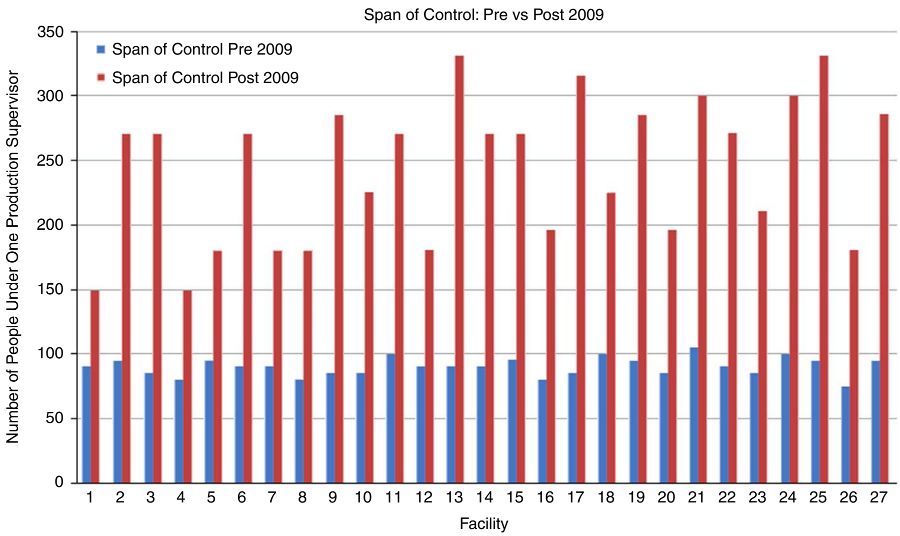

Figure 9. Span of control increase pre vs post 2009

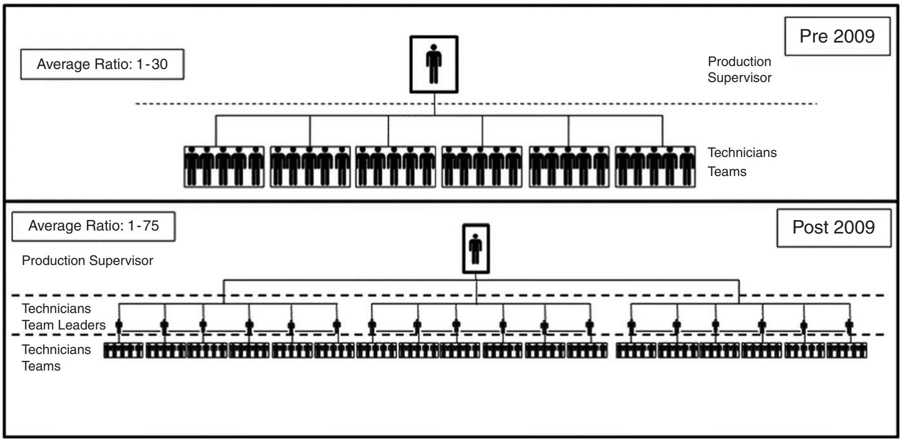

Figure 10. Span of control increase pre vs post 2009

- randomly inspect conducted/completed jobs in the zone;
- monitor and control technician training and rotation on jobs in the zone;
- update the metrics board;
- conduct safety talks;
- conduct team meetings and resolve issues arise; and
- communicate with supervisor for the required support.

The following is some of the concerns and issues noted during the conducted facility visits:

- The Toyota team leader system is implemented in a non-union environment.
- Union employees cannot supervise other union employees (by UAW contract Article VI, Section 1). Therefore, the team leader can give direction, and it is up to the technician to follow or not.
- Managers interviewed indicated that most of the team leaders are given position by seniority. Capability was not the criterion for selection in most cases.
- Mangers indicated that the new system was decided on by upper management and implemented within two-month period.

In theory, since the supervisor in the new system (post 2009) adopted at the Big Three will only deal with the team leaders, his or her span of control will increase, but without increasing work load. In practice, the supervisors interviewed at the Big Three indicated the following:

- The changes in the span of control took place within one month, and issues such as team leaders and responsibility were determined after.
- They are in daily contact with technicians; in most case resolving and directing technicians to perform certain tasks, due to the conflicts and UAW supervision agreement mentioned above.
- Most of the team leaders lack the skills in a certain area which require the supervisor to perform their jobs. Based on the inputs from managers at facilities visited, 75-90 percent of team leader call for supervisor intervention on daily bases.

For example, some team leaders do not know how to get information and update board charts in Microsoft Excel or PowerPoint.

- Most team leaders lack technical skills.

The comments and the results achieved indicate that the upper management's "need" to look decisive undermines the value of giving the process its necessary time in order to assess, evaluate, and adjust strategies before implementing the new span or control structure.

4.2 Efficiency comparisons pre 2009 and post 2009

Improving labor efficiency directly reduces the cost of manufacturing and assembly. The objective of each facility is to increase efficiency to an optimal level. According to the Harbour (2005) report, automotive companies such as Toyota operate at 96-126 percent utilization. Some of the advantages of improving efficiency and utilization include (Wilson, 2010):

- reduce labor cost;
- reduce tool and machinery usage;
- reduce work in process;
- improve quality control; and
- others.

Authors such as Morgan (2006) indicate that increasing efficiency without providing proper training, equipment, tools, work zone area, and team support will lead to deterioration in SQDCME. The average labor efficiency increase for the Big Three is 21 percent as illustrated in Table VI. A question was presented to the facilities personnel about the discrepancy between improvements in efficiency and deterioration in facility output variables. The managers indicated that the top 3 reasons that the improvements in output variables were not the same as improvements achieved in labor efficiency are the following:

- 98 percent of managers indicated that the number 1 issue is increasing supervisor subordinate technicians. There is a lack of supervisors' time to respond to issues and concerns during the production shift.
- 95 percent of managers indicated that the number 2 issue is lack of proper training. Technicians' responsibility is increased with minor or no training given.
- 60 percent of managers indicated that the number 3 issue is employee classification. For example, if technicians find a problem they will not fix it due to classification restrictions and they need to call an inspector or a team leader to fix it. This issue can be resolved by eliminating the different employee classification, which is the case at Toyota, Honda, and Nissan (Reliable Plant, 2010).

Table VI. Labor efficiency improvement for the big three pre 2009 to post 2009

Department	Pre 2009 (%)	Post 2009 (%)	% increase
Chassis	61	65	7
Trim	58	71	22
Assembly	52	70	35

The span of control has been increased drastically from the years prior to 2009 to the years post 2009. The average ratio of the span of control was 1-30 pre 2009 and augmented to 1-75 post 2009, which, however, is not the optimal level. This, nevertheless, has increased efficiency in the facility, even though some miscommunication has taken place.

5. Implication and conclusion

The main implication of this study is that the span of control has increased beyond what scholars and researchers have addressed in the past. This may be due to the advancement in technology, skills, and new expertise. Achieving an efficient and practical span of control number in the automotive industry is a challenging task which requires time and support of every discipline within the organization. Increasing the span of control without improving the skills of employees and/or technicians will lead to deterioration in operation performance metrics. The task of increasing the levels for a span of control will provide improvements required only if the new level has the capability to perform its task. The data indicates that the lower the span of control the better the business metrics. According to Curt Towne, one of the production managers interviewed, the cost of increasing the span of control cannot be justified based on the deterioration in the output variables. When presenting the result to one of the controllers at the Big Three facilities, he indicated that the cost associated with the increase in quality problems for the program life time (five years) at his facility is 324 percent more than the cost reduction achieved by increasing team size and reducing the number supervisors.

It is clear that the upper management must adapt their methods to suit their needs. For example, in an area that requires higher skilled employees, the span of control must be lower than the area that does not require as many skills. In addition, issues such as the ability of team leaders in directing technicians must be addressed (i.e. resolve issue with the support of UAW), as well as providing proper and frequent training to employees. Moreover, the team leader position should be based merely on capabilities and skills. Addressing such issues will surely improve the business metrics such that the span of control can be increased without deteriorating safety, quality, and cost.

Future work conducted in this area should focus on topics such as standardization of team leader assignment, limitations and responsibilities of supervisor, span of control in other industries in comparison to automotive utilizing similar metrics, and the impact of span of control on other metrics such as material handling, labor relation, and in-station quality.

References

Dolgui, A. and Proth, J.M. (2010), *Supply Chain Engineering: Useful Methods and Techniques*, Springer, London.

El-Khalil, R. (2009), "Optimization of flexible body shop system, section II", doctoral dissertation, retrieved from ProQuest Dissertations and Theses, Accession Order No. AAT 3356289, Lawrence Technological University, Southfield, MI.

El-Khalil, R. (2013), "Effectiveness of increasing span of control on operational performance", *24th Annual POMS Conference, Denver, CO, May 3-6*.

El-Khalil, R. (2015), "Simulation analysis for managing and improving productivity", *Journal of Manufacturing Technology Management*, Vol. 26 No. 1, pp. 36-56.

El-Khalil, R. and Halawi, L. (2012), "Benchmarking – automotive facility layout, JPH, and over speed", *Allied Academy International Conference*, *February 12, New Orleans, LA*, pp. 19-23.

Geismar, N., Dawande, M. and Sriskandarajah, C. (2011), "Productivity improvement from using machine buffers in Dual-Gripper cluster tools", *IEEE Transactions on Automotive Science and Engineering*, Vol. 8 No. 1, pp. 29-41.

Gittell, J.H. (2001), "Supervisory span of control, relational coordination and flight departure performance: a reassessment of post bureaucracy theory", *Organization Science*, Vol. 12 No. 4, pp. 468-483.

Hopej, M. and Martan, J. (2006), "The determination of span of control", *Operations Research and Decisions*, Vol. 2 No. 1, pp. 55-62.

Kawai, N. (2011), "Does downsizing really matter? Evidence from Japanese multinationals in the European manufacturing industry", *The International Journal of Human Resource Management*, Vol. 1 No. 1, pp. 1-19.

Kim, J., MacDuffie, J.P. and Fill, F.K. (2010), "Employee voice and organization performance: team versus representative influence", *Human Relations*, Vol. 63 No. 3, pp. 371-394.

Kouvelis, P. and Li, J. (2009), "Flexible backup supply and the management of lead-time uncertainty", *Production and Operations Management*, Vol. 17 No. 2, pp. 184-199.

Kouvelis, P. and Tian, Z. (2013), "Flexible capacity investment and product mix: optimal decision and value of postponement options", *Production and Operations Management*, Vol. 23 No. 5, pp. 861-876.

Levine, D. and Tyson, L. (1990), "Participation, productivity, and the firm's environment", in Blinder, A.S. (Ed.), *Paying for Productivity*, Brookings Institution, Washington, DC, pp. 183-244.

Liker, J.K. (1998), *Becoming Lean: Inside Stories of US Manufacturers*, Productivity Press, Portland, OR.

McConnell, C. (2000), "The changing face of health care management", *Health Care Manager*, Vol. 18 No. 3, pp. 34-39.

Morgan, R.A. (2006), "Creating organizational alignment", *Association for Manufacturing Excellence*, Vol. 22 No. 2, pp. 45-48.

Neilson, G. and Wulf, J. (2012), "How many direct reports?", *Harvard Business Review*, Vol. 90 No. 4, pp. 112-113.

Nevins, J.L., Winner, R.I. and Reed, D.L. (2003), "Ford motor company's investment efficiency initiative: a case study", *Handbook on Enterprise Architecture*, Springer, Berlin Heidelberg, pp. 683-724.

Orlando, R., Ford, D. and Ismail, K. (2006), "Exploring the performance effects of visible attribute diversity: the moderating role of span of control and organizational life cycle", *The International Journal of Human Resource Management*, Vol. 17 No. 12, pp. 2091-2109.

Reliable Plant (2010), "Toyota makes changes to organization structure", available at: www.reliableplant.com/Read/27981/Toyota-changes-organizational-structure/ (accessed May 20, 2013).

The Car Connection (2005), "Toyota, GM tops in '05 Harbour Report", available at: www.thecarconnection.com/tips-article/1007446_toyota-gm-tops-in-05-harbour-report/ (accessed July 2, 2013).

Tsai, C.F. and Shih, C.T. (2012), "Labor union negotiations: stepping stones or stumbling blocks for a responsible downsizing strategy? Empirical tests in Taiwan", *The International Journal of Human Resource Management*, Vol. 24 No. 3, pp. 601-620.

Wilson, L. (2010), *How to Implement Lean Manufacturing*, McGraw-Hill, New York, NY.

United Nations Industrial Development Organization (2010), "World manufacturing production", available at: www.unido.org/resources/statistics/quarterly-report-on-manufacturing.html/ (accessed February 15, 2015).

US Department of Labor (2010), "Injuries, illnesses, and fatalities", available at: www.bls.gov/iif/ (accessed May 20, 2013).

Wunker, S. (2012), "Fiat's smart US launch strategy-really", available at: http://blogs.hbr.org/cs/2012/02/fiats_smart_us_launch_strategy_really.html/ (accessed March 18, 2013).

Further reading

United States Department of Labor (2011), "Wage and hour division (WHD)", available at: www.dol.gov/whd/fmla/2010ndaa.htm/ (accessed January 22, 2013).

Wad, P. (2012), *Impact of the Global Economics and Financial Crisis over the Automotive Industry in Developing Countries*, United Nations Industrial Development Organization, Vienna.

About the authors

Raed El-Khalil is an Assistant Professor at the School of Business (ITOM), Lebanese American University, Beirut, Lebanon. He holds a Doctorate Degree in Manufacturing Engineering from the Lawrence Technological University, USA. He is a consultant for several manufacturing companies in North America. His articles have been published in professional journals such as *Benchmarking: An International Journal*, *Journal of Manufacturing Technology Management*, *International Journal of Industrial and Systems Engineering*, *The Business Review-Cambridge*, *The Journal of Developing Areas*, *Academy of Information & Management Sciences Journal*. His research interests are in manufacturing strategy, sustainability, lean and flexible management, and international comparative studies. Raed El-Khalil is the corresponding author and can be contacted at: raed.elkhalil@lau.edu.lb

Abdul-Nasser El-Kassar is an Associate Professor in the School of Business, Lebanese American University, Beirut, Lebanon. He was awarded a PhD in Mathematics from the University of Louisiana – Lafayette. His research areas include production planning and inventory control, security and cryptography, abstract algebra, and number theory. He has many publications in peer reviewed journals and conference proceeding.