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OPEN ACCESS ARTICLE

EXPLAINING COMBAT STRESS AND ITS EFFECTS ON DECISION MAKING IN THE THEATRE OF OPERATION

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Abstract

Combat stress and decision-making process in dynamic contexts are almost unexplored and still incompletely clear to the scientific community. On the other side, both are some key aspects of combat performance. Operational psychology is focused on using psychological knowledge in enhancing operational performance. First is necessary to understand their nature and relationship, in the direction of making strategies for training and dealing. Stress is productive when is optimal, while decision making process has its specifics in dynamic and risk contexts. Stress has an impact on decision making process, but their relationship is still unclear, as well as whether they can be seen as a related concept or separate phenomena. However, both are based on certain psychological processes, whose understanding and impact can lead to necessary changes in performance as a human behavior, and whose are base for mental readiness training programs. It is recommended to include these programs within the basic military training, to enhance military performance.

Keywords: *Combat stress; Operational performance; Decision-making; Military psychology.*

INTRODUCTION

Operational psychology is a relatively new area of psychology that deals with the "operational" side of military and law enforcement, focused on the psychological information that is relevant for these specific populations, within their similarities. Psychology as a scientific area deals with human behavior, its explanation and prediction, while psychological applied branches' main goal is to find ways of human behavior changing in accordance with the needs of the society, groups, and organizations in it. Military and law enforcement, especially with high demand, high reliability, and risk professions within them, are dealing with high-risk social goals and using expensive equipment, that needs expensive training and personnel readiness. All this confirms the need of investment and special care of personnel, that implies enhancing of their professional knowledge as well as their mental health and expiration

date extension, which is unimaginable without implementing relevant psychological principles, practices, and research.

According to that, the main idea of this text is making an overview of some current knowledge about two crucial aspects for understanding human behavior, towards enhancing combat performance. Given the distance between laboratory and field, research on this subject is rare and literature is limited. So, presenting some information about nature and relationships will open discussions about possibilities of neutralization some negative impact, to consider some steps toward maximizing the positive effects in combat.

An attempt to explain combat situations is facing with the dynamic interpretation of the human behavior complexity in groups under unpredictable environment and stress. Stress has its impact on the psychological and physiological function that affects human behavior and the performance on the field, which has special implications in the case of leaders. One aspect of the field performance is decision making, as a psychological process that determines the whole behavior and has its impact on the situation in dynamic circumstances, as well as psychological processes and behavior of the other team members. It suggests the need for a multi-variable, complex and interactive model that can explain generation and coping with stress in combat, the way of its impact on the decision-making process, and the ways of its prevention and management.

What is stress?

There is no scientific consensus about the definition of ***stress***, nor does there exist an official theory for reliable prediction of human reactions in the special conditions of environmental stress, especially in combat. In military psychology literature research is mostly focused on detecting modern military stressors or explaining relations of combat stress with other variables during different kinds of military training. When the definition of stress is discussed, mainly is presented Sally' (1976) pioneer *endocrinological approach* of stress as external stimulus or psycho-biological response, vs. recently most accepted Lazarus' *transactional approach*, by which stress has psychological nature and is viewed as a relationship (transaction) between individuals and their environment. He distinguishes the source of stress or ***stressors***, as external event or internal request, from ***stress*** (harm, threat or challenge), as internal state or experience that comes from two mediating processes: *cognitive appraisal* of personal significance of the specific event (*primary appraisal* - interpretation of the situation) and *coping strategies* used by the individual to cope (*secondary appraisal* - interpretation of the coping possibilities). ***Coping,*** determined as personality' efforts to manage demands, conflicts and pressures, that outperform person' resources, has been studied extensively, but researchers haven't reached a consensus about its nature yet. Opposed to *coping as personality trait*

which guides to enhancing that trait for adapting to stressful situation, is approach of *coping as a response caused by a match between traits and specific stressful situation* that guide to enhancing some traits (eg. performance-related) in specific situations (eg. performance-related stressful situation). Thereby, ***coping strategies*** can be generally (Lazarus & Folkman, 1984):

1. Problem/ task-oriented - focused on task goal accomplishing and minimizing or modifying the stressors,

2. Emotion-oriented - alleviation or elimination of the emotion's consequence of a stressor, not on a stressor from the situation, that are effective for stressors that are uncontrolled and brief, but less for combat stressors, and

3. Avoidant focused – diverting attention from the stressful situation.

In the military case, occupational stress can be organizational, operational, and combat. While ***operational stress*** refers to operational environment and operational tempo, not directly associated with combat (hard training, rules, friends in danger), ***combat stress*** refers to the extent of stressors (physical, environmental, cognitive, and emotional) present in the combat environment. According to intensity, unpredictability, and risk, most like combat stress is ***acute stress in crises***. On the other side, ***organizational stress*** is related with military organization, organizational structure, and life, which is mostly of chronic nature (and is not a focus of this work). Stress and stressors defer from the ***combat/ operational stress response/ injury***, that refers to reactions (physical, behavioral, and social) experienced during or after a combat deployment and other stressors, that are descriptions of normal human reactions to extraordinary events, but which can finish with PTSD, as a kind of psychological diagnosis.

Thereby, it is important to make difference between ***causes (stressors)*** that can be *enduring* or *cumulative* (ex. fatigue or boredom) or *acute* (ex. threat) and ***stress symptoms or outcomes of stress***, that can be *long-term* (PTSD) and *short-term*, as well as between *mental health* and *performance outcome*. Thus, in the military, especially Special Forces and missions, the biggest accent is placed on prevention strategy, where education, training and social support have been proved as most effective approaches. Most important aim in it is improving ***stress tolerance***, as capability to stay cool or not let emotional and physiological reaction to interfere with the cognitive processing, which is harder in ***acute crisis situation***, characterized as with a sudden change in the situation with a loss of resources for the individual (Gaillard, 2003).

It is important to emphasize that the "modern war" operations vary between high-intensity combat, peacekeeping, and stability operations, to humanitarian or nation-building projects. So, they include a wide range of stressors, related to extreme stress exposure in combat up to capabilities of successful coping with shifting challenges of war and peace building. All this suggests the need for different training approaches. In extensive study, Barton distinguishes six primary stress dimensions: isolation, ambiguity, powerlessness, boredom, danger, and workload (Bartone, 2006). Given that all members are vulnerable to insurgent attack, and it is considered the most extreme war theatre, the text is focused on explaining combat stress and factors related with its existence.

Models of combat stress

To emphasize an appropriate model, it was shown that there are studies that outlined variables related to combat stress, but a coherent scheme of their relations lacks its face validity. It is almost impossible to conduct research and confirm some theories and hypothesis out of the real combat situation, so hence existing models are based on war experience of some combat leaders. Gal and Jones' model (1995) includes number of antecedent variables that are acting through mediating variables (even without clear-cut distinction between them) in affecting individual appraisal of the combat situation, and result in modes of response and coping with the real combat situation. **Antecedent variables** are in the background of the combat situation and can be:

1. Individual factors: *personality dispositions* as long-standing factors (limited evidence, but tendency is toward considering traits for selection for combat roles, leadership roles and special operation), *individual's well-being* refers to the relationship with the environment (positively related with ability to face with stress), *previous combat experience* (enhancing, against fear, or inhibiting effect, if it was traumatic), *role in combat* (*formal* - leadership role is less stressful, or *assumed* – expectations, mastery and concentration to tasks distract attention from danger; both have crucial role in appraisal).

2. Unit factors that determinate *unit climate*: *unit cohesion and morale* (law level of moral and weak bonds with comrades and leader positive relate with loneliness and low self-esteem, that concern military performance and intense perceived stress in combat), *confidence in commanders* (essential and critical role in coping with stress in combat, especially believe in professional competence, than believe in credibility and perception of care; confidence is linear with the command level before battle, but it trend is reversed after combat), *confidence as a soldier* (confidence in skills and weapon increase battle skills, that improves with training, especially simulations), *ideology, values and*

commitment (believes of homeland defending give additional strength, but the solidarity with soldiers next, is main maintainer of survival in the battlefield), and

3. Battlefield factors: *type of battle* (stress is higher in static than in mobile situation, higher in defensive than offensive operations, no clear data for day or nighttime), *length of exposure* (correlate with cumulative stress, so consequences are combat exhaustion and fatigue, and there is a limit to breakdown) *and intensity of combat* (correlate with acute stress with consequence of battle shock), *battle anticipation* (may be more stressful than acute battle, named as "pre-combat syndrome", the relationship is inverted U with positive feeling of combat, as a result of two conflict tendencies – relaxation and excitation – fused in "incubation of threat"), *uncertainty* (temporal – when the time is unknown, and event – when the nature of event is unknown, both are positively related with stress) and surprise (mostly surprise aversive event, that maximize panic and breakdown), and *environmental conditions* (new and unfamiliar environment without acclimatization, especially adverse environment, is positively related with combat breakdown).

Mediating variables have *cognitive* (interpretations of the antecedents, logical evaluations of the situation and building expectations of behavior and situational consequences) and *dynamic quality*. It is mostly *controlled by the commanders,* which acts as a lens - focusing the antecedent variables into a unified interpretation of situation (as optimal and create successful expectations).

Appraisal process is the bridge between the external conditions and soldier's response. Involves mental activities such as judgment, discrimination, and choice of activities, and can be explained as soldier's perception and evaluation of the situation and his capabilities to cope with them. Those processes differ depending on individuals and situations and determine the individual' course of action in different combat stressful situations.

Modes of responses can be *physical* (autonomic, musculoskeletal, and glandular changes), *emotional* (affective reactions), *cognitive* (perception distortion, hyper alertness, increased automatic and over learned responses) and *social*. They are universal, mostly involuntary, automatic, and immediate, and just to some extent can be conditioned by training. In this case, training needs to introduce soldiers for these reactions and provide acceptance of them as normal body preparedness for the combat.

Modes of coping are integration of the individual appraisal and variety of response, and can have various levels of *active* (preparing for combat and activities during combat, that mostly have positive consequences and lead to optimistic reappraisal) and

passive modes (inactivity, apathy or lack of initiation, which consequences of ineffective performance to beginning of psychological collapse) to complete breakdown (combat fatigue, battle shock, war neuroses that is manifested in removal from the battle, immobility or unpredictable behavior). Modes of coping are voluntary, flexible and its time of expression can be personally controlled, so those are psychological aspects that are central target in the training. They can be influenced by training and strongly determined by the combat situation, but in the same time give input in their reappraisal (Jones et al., 1995).

Pavlina et al. (2000) developed another model that is based on the previous one, which includes six aspects:

1. Battlefield-related factors – intensity and duration of combat operation, material and manpower of attacking and defending forces, and taking care of warfare international norms and conventions.

2. Stress prevention factors – individual (selection and classification and combat readiness of the military personnel by the psychological preparing techniques and combat training), unit (group cohesion and interpersonal relations) and social (family and broader community detachment).

3. Leadership factors – proper selection and training of leaders (unit, field and senior level);

4. Experience and appraisal of combat situation – combat stressors can be: psychological (cognitive and emotional), physical and physiological.

5. Combat stress reactions – psychological (cognitive, emotional, and motivational), physical and behavioral, and

6. Combat stress effects – different stages: psychological shock, immediate, acute, and chronic.

Decision-making: aspects related to high-stress situations

The definition that is focused on psychological aspects and uncertain and complex environments, defines the ***decision making*** as psychological process of choosing between various alternatives with the intent of reaching maximal number of goals, while avoiding damage and unnecessary risks and by using a minimal amount of resources. In a stressful situation typical for the military reality, important role in the decision making play many factors, as: the level of decision making, relevant personality traits, dynamic life-threatening environment, uncertainty, time criticality etc. (Heichal, 1992).

Difference in the *hierarchical level* of decision makers include difference in cognitive processes that are involved, difference in available time that have consequences on the decision making process nature and the way how it's organized (number of people involved, primary aim – reaction of the changing environment or planning the future, whether the rules exist or have to be made), as well as difference in the stress effects for various situations. The process on the *tactical level* is action oriented, characterized as a reaction task, where basic problem is appropriate recognition of situation' nature and choosing a correct procedure, more automatically oriented (reflexive), that need split-second decisions, which capabilities are the base of the military training (Ranyard et al., 1977).

At the highest level this process is cognitive and systematic, oriented to decision making steps prescription, in which *systematic process* has seven steps: defining the goal, examination of all possible alternatives, their cost and benefits review, systematic search of new information for their evaluation, evaluation of the new information even they contradicts to chosen alternative, repeated examination of alternatives outcomes, making decision with finished preparations to enable its implementation (Gal, 1991).

At any moment in decision making process during emergency, several factors have significant impact on the ability to solving complex problem in a limited time: psychomotor skills, knowledge and attitudes, information quality and completeness, stress generated by the actual problem or any other existing background problem, or the complexity of elements that must be attended to.

Defining *risk* as a combination of probability of an unfavorable outcome of the mission success or performance, the decision maker with risk-averse, risk-neutral, or risk-prone attitude will make different decision in the same problem. Thus, making decisions in stressful environment whether decisions are immediate or delayed, usually suffer from uncertainty and imperfect information of the present. *Uncertainty* because of lack of information in the scope of decision and the probability of the appearance various results reached by making a specific decision. So, *immediate decisions* need more flexibility in designing strategy and making decisions given that they are based on imperfect knowledge, but uncertainty resolution at an early stage and no existing difference in time of resolution and time of consequences gives possibility of decision application in the best possible way with minimized worry time, that can be taken as advantages (Keeney & Raiffa, 1976).

Thus, in dealing with uncertainty in a continually changing environment the decision maker must achieve a trade-off between the cost of action vs. the risk of non-action and

make decisions based on available information that are many times incomplete. The effective outcomes that achieve both kinds of judgment – analytical vs. intuitive in the situation of emergency, given that they follow different cognitive path (Hammond, 2000).

What differ decision making during intense stress from the systematic one also is *time criticality* that both with stress are subjective states, in which person feels that situation is complex, information is incomplete, time is short, real threat exist and failure consequences are extreme. In this case, less time is spent on alternatives identification, negative information has bigger influence while important can be neglected, automatic decision-making tendency is increased, and the number of mistakes can increase even in simple situations. So, the latter performance quality inversely is related with the quantity of decision-making stress influence, and the ability to deal depends on decision maker subjective perception, its appraisal of the situation severity, methodological decision-making process implementation ability, personal attitude, and previous similar experience (Cohen, 2004). In short, the focus is on perception and coping, which abilities upgrade are the base of the mental readiness trainings for intense stress situations in the military.

Theoretical construct that is often used to explain the performance changes due to stress ***arousal theory***. There is an inverted U-shaped relationship between arousal and task performance, so performance decreases when arousal is either too low or too high and is optimal at intermediate level. The stress level should be high enough to stimulate top performance, but not enough to over-stress the body, considering that performance declines as the body moves toward exhaustion (Yerkes & Dodson, 1908).

The relationship of stress to judgment and decision making remains relatively unexplored aspect of human behavior, so literature is limited and not always conclusive. There are only few reliable empirical studies about stress effects on decision making process, mostly because of the difficulties caused by the ethical limitation in their realization, as well as enormous number of variables that have impact at the same time and which relationships are also important. So, the results of this research are still uncertain. Some empirical results show that combat stress reduces operational effectiveness by different impairments on the perceptual and cognitive abilities, influenced by the negative emotions that have negative impact on decision making, exposed as: attention lapses, narrowing of perceptual focus, short-term memory impairment, biased information processing etc. that will be shortly explained.

Threatening stimuli are detected more efficiently than neutral and positive one, so with their appearance in the environment, attention is immediately focused (locked) on them influenced by the negative emotions (as fear), while thereby quickening response time

and neglecting other stimuli or failing other tasks. Well-known natural phenomena, called *attention tunneling* or *tunnel vision*, occurs because of the adrenalin releasing as a survival mechanism in danger, to prepare the body for handling a threat, which is detrimental when other important information is ignored (Godnig, 2003).

Lower working memory capacity, specifically in case of the higher emotionality, is related to more shooting mistakes, in case of making decision whether to shoot or not in a dangerous environment (Kleider et al., 2010). It was shown that higher level of threat correlated with less cognitive ability and higher feeling of resignation and helpless, greatest negative impact on cognition have strong feelings of anger and fear, different coping mechanism have influence on the performance in threatening situations as key mediators, low need of rationalize action associates with better cognitive functions in threat incidents (Wallenius et al., 2004). In the presence of threat, humans are biologically predisposed to subconscious reactions rather than conscious thought processing, to eliminate or reduce the imposing threat. While conscious perception forms a representation of an environment, subconscious perception directs the actions towards the environment and includes stimuli that do not reach conscious awareness. But if attention that helps person to sort information needed to perform some tasks, occurred solely on subconscious level, behavior would be difficult to take control. It would not be an intentional and controlled process, but a reactive subconscious process where action will be based on every aspect of environment (Gazzaniga, 2004). So, enhancing perceptual accuracy was shown that increases with actual combat experience, for which traditional military training was found that pays not enough attention (Thomas et al., 2004).

Mental readiness training: Effectiveness and importance for the military operations

To prevent operational effectiveness by reducing errors in field judgments and performance caused by combat stress, beside the selection phase, mental readiness training programs are developed for performance, injuries, and well-being military personnel protection. *Mental readiness approach* includes connection of stress management principles directly into meaningful training situation – giving directions how simulations as a cost-effective model need to be used, which means making combination of psychological coping principles with dynamic military stressful environments. While traditional military training is aimed at skill acquisition and retention by well known drills technique, stress training is aimed to improve *stress tolerance*, or the ability to maintain effective performance in dynamic high-stress

environment. In short, *drills* are responses that soldiers are taught to show in certain situations. They are trained intensively and frequently and become automated responses, so less suffer from combat stress than those that need cognitive control. But drills as dominant or well-learned responses will only be adaptive if the situation that triggers this response is like the situation in which the response is learned. This misses to teach individuals in adaptive coping mechanisms or cognitive flexibility under unpredictable adverse circumstances that are different from those in training (Delahaij et al., 2006).

Thus, in order of effective application, stress training should be an integral part of military training and consider the military culture, which need a mix of psychological, operational and technical experienced trainers, as well as very hard psycho-physical readiness of candidates. This opens some discussions about mental readiness trainers' competences and their relationship with the military commanders. The gap and tension that long existed between the two kinds of professionals lie in the fundamental difference in the way which stress is perceived, as well as in the adverse stress reactions treatment – are they medical problem and should be avoided, or it is a weapon used for reducing will and effectiveness of the opponents.

Opposed to inappropriate approach of psychological professionals, is the fact that military leaders are not able to manage combat/ operational stress control (prevention, early identification, and optimal management of adverse effects) by themselves (Nash, 2006). On the other side, in order lessons to be absorbed and not failed, mental readiness trainers need to have operational credibility with military personnel, implicitly and explicitly to endorse these fundamental principles, as well as to be placed in the regiment, in case to be implemented and supported by the military unit and life. Thus, considering that mental readiness training is one of the important phases against PTSD and maximal operational effectiveness, must not be abandoned the importance of the military leadership as its mediating factor, as well the need of close coordination among the two kinds of professionals, during both the training and operations (Thompson & McCreary, 2006).

The set of psychological techniques, generally called ***Stress Management Training (SMT)*** are used for preparing soldiers for potentially highly stressful situation in a long-term perspective, and involve relaxation, cognitive restructuring, problem solving, social skills training, planning behavioral changes and exposure to stressful situation, etc. SMT diminishes negative reactions to stress by upgrading personality' capabilities for more successful coping, that results in lowering the incidence of PTSD. According to Murphy and Sauter (2003) SMT can have better application by dividing the interventions in three phases:

1. Primary, focused on changing the source of stress (or stressors) by changing environment or etc., as a stress prevention.

2. Secondary, reducing the symptoms associated with stress before their crystallizing into disorders, and

3. *Tertiary interventions* that includes treating psycho-physical disorders.

Most common are the second one, that are most related with current problems coping. Despite SMT that is no coherent set, there are some consistent intervention programs with strategies that are carefully selected among those who include SMT and will be shortly explained (Ovuga, 2012).

Stress inoculation training (SIT) is set of cognitive-behavior techniques, such as imagery and behavioral rehearsal, role play, modeling, and progressive exposure to stressful situations, unfold in three phases:

1. Conceptualization

2. Skills acquisition and rehearsal, and

3. Application and follow through.

The aim is to help for more successful coping with the consequences of being exposed to stressful event, by immunization through progressive exposure, as prevention. It is an intensive multi-stage process of replacing ineffective thoughts, in order to change or reduce maladaptive behavior in combat situations.

Stress exposure training (SET) is spreading the SIT out of its traditional clinical application explicitly focusing on enhancing the effectiveness of operational performance in military personnel by reducing negative responses. SET as SIT same involve three phases:

1. Educational – discussion about typical stress reactions and identification of individual reactions that are target of SET, by understanding and assimilating these new experiences and upgrading their motivational level to complete the training.

2. Specific stress coping skills development, by development the stress reactions awareness ability, as well as building cognitive, emotional and behavioral specific stressful environment control strategies, by the trainer's feedback.

3. Practice of new strategies in increasing stress simulation situations.

The second phase involves nine strategies, as: cognitive control techniques, psychological control techniques, intentional overlearning of cognitive and motor skills,

mental practices, concurrent task development, guided error training, decision-making training, enhancing adaptability and team training (Cannon-Bowers & Salas, 1998).

The third phase is simulation-based, that mostly correlated with real-world environment. It has been shown that are most important and used for increasing accuracy in high dynamic, complex and risk professions, especially for military operations. Future research is directed to examination of mediation variables and SET transfer principles from training to operational environment (Ross et al., 2004).

Anxiety management training, developed by Richard Suinn, is as well cognitive-behavior based, but is focused on learning relaxation and its generalization on daily stressors. Two spots are recognized:

1. *Emotional, cognitive and physical signs* related to anxiety detection, and

2. *Reaction to these signs on way to make them disappear*.

Specific is that it is not required to find the causes of anxiety, but the focus is on its recognition and neutralization. While, firstly was created for anxiety disorder treatment, and later had been used wider, as well as in enhancing performance by general stress reduction (Suinn & Richardson, 1971).

Other important aspect for stress management or improving decision making process in high reliability professions, is efficiently ***coping with complex and unforeseen situations***. This topic is included in traditional training programs (focused on enhancing cognitive control over negative stress reactions and to the question *"How to process and control")*, and in some new approaches (focused on development of openness and acceptance attitudes that helps for efficiently structure of those kind of situations, answering the question *"What to process and control")*. Type of traditional training based on *Critical Thinking Instruction* provides formalized questioning scheme for looking relevant cognitive processes and representation that are used to control the though process for managing a situation, as well as other psychological techniques, as relaxation, biofeedback, or metacognitive techniques as cognitive restructuring and etc. New approaches involve *Thinking dispositions concept,* that build executive processes that allow effective processing of information identified as relevant, and then reflective processes that allows relevant situation structuring, assign its meaning and build relevant framework; and *Mindfulness concept*, that put accent on directing whole attention on present experience with accepting the state of mind or avoiding as much as possible reacting on it or judging its context, that encourage keeping in touch with deviant elements, making relevant analysis framework and identifying appropriate automatic reactions (Fornette et al., 2015).

CONCLUSION

Combat stress and decision making are significant aspects in the theatre of operations. Both are based on complex psychological processes, which understanding can help in enhancing military performance as well as are crucial in personnel mental health protection. Current knowledge has no complete explanation of their complex nature and interrelationship, given that research possibilities are limited. Mental readiness training is mostly based on upgrading coping capabilities, enhancing perceptual accuracy and cognitive restructuring for effective information processing, to minimize negative stress effects by advancing their control. Future perspective should be directed on implementing mental readiness training in the basic military training program as well as on some research about maximization of the training transfer and mediating variables discovery. This implies appropriate educated and trained mental readiness professionals, as well as their close coordination with the military professionals and leaders, which is conditioned by long existed gap removal.

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MACHINE SCHEDULING AND SPREADSHEET MODELING IN A FASHION MANAGEMENT CLASS

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Abstract

This paper is a result of several semesters of teaching an Operations Management class in the Fashion Management program. Topics like flow shop and parallel machine models are traditionally discussed in an Industrial Engineering class. However, we discussed these topics successfully in a fashion management class by providing examples that our students could relate to. This included examples in apparel production and fashion retailing. The students were also able to learn several logical Excel based formulas while creating spreadsheets for these topics. For the flow shop model, we create a spreadsheet model that reflects all details of the Gantt chart including idle times. In the case of parallel machines, the spreadsheet involves the more complex Nested IF functions. The students showed enthusiasm even when creating the more challenging spreadsheet models.
Keywords*: spreadsheet modeling; Flow shop models; Parallel machines; supply chain.*

INTRODUCTION

Fashion Merchandising and Management (FMM) is the largest major in the School of Business at Thomas Jefferson University. In addition to specialized coursework in FMM, these majors are also required to take all the core business classes that are typically taken by other traditional business majors. We also have several FMM majors who choose Finance or Accounting as their minor areas of study. Such coursework prepares these students very well when they seek full-time jobs upon graduation. While several of our FMM students obtain jobs in the retailing industry, some of the technically inclined students seek employment in apparel manufacturing and production. Some students eventually start their own boutiques or related entrepreneurial ventures. Since our FMM majors are required to take all business core courses, they are comfortable with quantitative coursework like Business Statistics and Operations.

Microsoft Excel is the most popular software program that is widely used in the industry. Its popularity is attributed to its unparalleled flexibility, versatility, and a wide range of

capabilities for data management, analysis and visualization. It is used by financial analysts, retails store managers, project managers, business analysts, accountants to name a few. Due to the increasing use of data-driven decision making even in the retailing sector and business in general, the demand for proficiency in Microsoft Excel has also increased significantly in recent years. Teaching spreadsheets is not specifically about helping students learn spreadsheets but to also help them grow to make more informed decisions as managers in the real world. Educational theory, such as Dale Edgar's Cone of Experience, suggests that learners remember 70-90% of what they say and do (active learning). Excel exercises or projects are considered as active learning (Braun, 2017).

Operations and Data Analytics is one of the core business classes which is required for all majors in the School of Business. This course includes the coverage of important topics like Inventory, Forecasting, Linear Programming, Supply chains, Waiting Lines, etc. Since FMM majors take specialized courses in their field, they have a firm understanding of concepts like Supplier Lead Time and opportunity costs (or loss of customer goodwill) due to shortages or late shipments. For example, they know that late shipments from their suppliers can be disastrous when the product is seasonal. This late shipment issue is highlighted in a Harvard Business Case (Hammond & Raman, 2006) which discusses the ski wear supply chain and the impact of late shipments in this highly seasonal business.

Flow shop and parallel machine models are topics that are traditionally found in Industrial Engineering coursework. Some pioneering textbooks provide various methods of scheduling (Bedworth & Bailey, 1982). Some quick and dirty manual methods have since been presented and discussed (Woolsey, 1971, 1982, 1990). Most business students have never visited a production unit. However, we believe that we can discuss these topics with our fashion students by providing real-life examples as well as examples in their field in addition to guiding them to create spreadsheet models.

We discuss two specific concepts in the classroom.

Concept 1 is about two serial processors better known as the two-machine flow shop model. We first present a pictorial solution by drawing a Gantt chart. We then create a spreadsheet model to reflect all aspects of the pictorial solution. To our knowledge, such a spreadsheet solution is not found in any textbook. More importantly, the students find this spreadsheet model easy to understand. We then ask our students to complete *Assignment 1* on three machines by providing a partial solution and some guidelines. An important hint given is that there will be another Idle Time column that must be included while creating the spreadsheet.

Concept 2 is about parallel (and identical) machines. Here, we review two numerical examples in the classroom. One example is to minimize the flow time of a set of jobs on three identical machines. The second numerical example is to sequence the jobs using the due-date rule to calculate tardiness and number of tardy jobs. These are also solved pictorially by drawing Gantt charts. We then create spreadsheet models that reflect the pictorial solutions. The students are then asked to complete *Assignment 2*, which involves solving a similar problem but with four machines.

For both Assignments, the students submit manual as well as spreadsheet-based solutions.

CONCEPT 1: A 2-MACHINE FLOW SHOP MODEL

This model involves two machines (or stages). Jobs must be processed on both machines by first going to Machine 1 (M1) and then to Machine 2 (M2). Interestingly, there is a simple real-life example provided by Martinich (1997). We refer to it as Numerical Example 1 and is presented below. Our fashion students relate to this model immediately when we also refer to *cutting* and *sewing* as another example of two important stages involved in apparel production.

Numerical Example 1

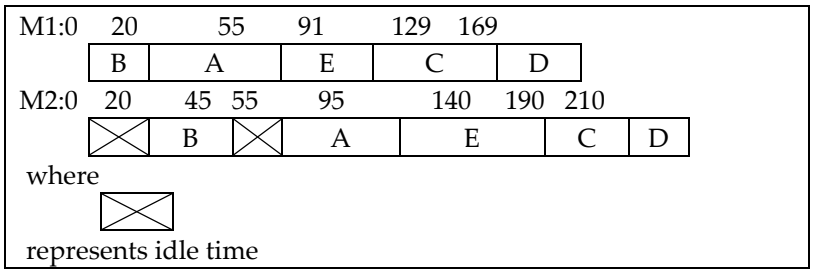
Joe has five loads of laundry to do before he can go to the beach. Based on the colors and fabrics, he has estimated the washing and drying times for each load (Table 1). All loads must first be washed and then dried (clothes that have been washed can sit in a basket waiting to go to the dryer so that the washer can be used.) Determine the optimum sequence to minimize make span and find the total completion time of all jobs.

TABLE 1

Load	Washer	Dryer
A	35	40
B	20	25
C	38	50
D	40	20
E	36	45

Since our main contribution is to create a spreadsheet model to closely reflect the Gannt chart, we will not delve into Johnson's Rule for the optimum sequence. This rule is found in various textbooks. Using Johnson's Rule, the optimum sequence to minimize make span is: B – A – E – C – D. And Figure 1 below presents a Gannt chart which clearly shows the start and end times of each job on the two machines. The Gantt chart also displays Idle times on M2.

FIGURE 1



We present a detailed Excel solution for the above example in Appendix – A**.** Our spreadsheet uses Excel formulas to calculate completions times of each job on both machines. It also calculates the Idle times on M2. Appendix – A also has Assignment 1 related to a 3-machine flow shop that the students must complete.

CONCEPT 2: PARALLEL MACHINES MODELS

Consider a set of *N* jobs having different processing times and a set of *M* identical (and parallel) machines which can process any of these jobs. If N ≤ M, then the N jobs are randomly assigned to one of the M machines and they get processed with no job waiting in line. If N > M, then the first M jobs are randomly assigned to the M machines and the remaining jobs are waiting for the next available machine to be processed. These waiting jobs can be said to be in a queue (i.e., waiting line) and the job that is first in this queue will go to the first available machine.

Specifically, let us consider N jobs and M machines where N > M and all the M machines are available. The goal is to minimize the flow time. Job flow time is defined as how long a job is in the system (i.e., from the time it entered the shop until the time it leaves the shop after being processed).

Upon reading the above description in this section, a business major may not be clear about what the above means or where it can be applied. Hence, we provide simple real-life examples of such scenarios. When we enter a bank during peak business hours, we are likely to see three tellers currently serving one customer each and about five customers waiting in a line to go to the next available teller. Interestingly, this is not only found in banks and post-offices but also a very common sight in various apparel and retail stores too. Numerical Example 2 given below is for 3 machines (equivalent to 3 check-out counters in a retail store). We use the first come, first served (FCFS) rule to pictorially illustrate the mathematics of parallel machines. The spreadsheet model is presented in Appendix B.

Numerical Example 2

Consider *three* machines (M1, M2, M3) in parallel and a total of *eight* jobs (A, B, C, D, E, F, G, H). The jobs and their processing times (in hours) are as given in Table 2. Consider these to be *identical* parallel machines implying that the jobs can be processed on any of the three machines.

TABLE 2

JOB	A	B	C	D	E	F	G	H
Processing Time (P)	10	20	11	21	22	50	40	60

At time t = 0, we assume that all machines are ready, and all jobs are available. Note that while the jobs have arrived around the same time, they arrived in the order A, B, C, D, E, F, G, and H. We use the FCFS rule since retail stores, banks, and post-offices implement FCFS sequencing. Such a rule is fair and simple to implement.

At time *t = 0*: Job A (10) goes to M1; Job B (20) to M2; and Job C (11) to M3. Note that Jobs B or C could also have gone to M1. However, the end result will still be the same in terms of total completion time of all jobs.

Jobs A, B, C will be completed at times t = 10; t = 20; and t = 11 on M1, M2, and M3 respectively.

At time *t = 10*: Job D (21) goes to M1 and is completed at t = 31;

At time *t = 11*: Job E (22) goes to M3 and is completed at t = 33;

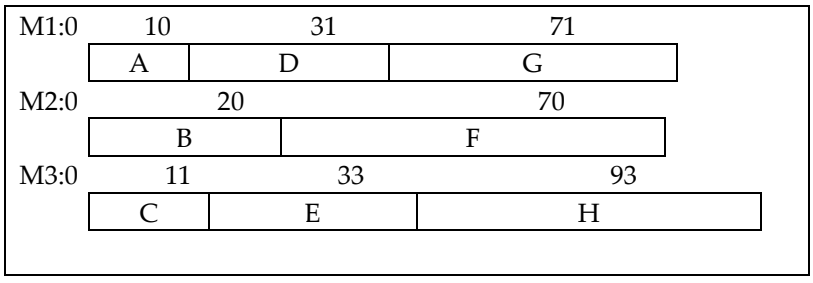
At time *t = 20*: Job F (50) goes to M2 and is completed at t = 70;

At time *t = 31*, Job G (40) goes to M1 and is completed at t = 71; and

At time *t = 33*, Job H (60) goes to M3 and is completed at t =93.

The Gantt chart (Figure 2) displays the start and end times of the eight jobs on the three machines.

FIGURE 2



We present a detailed spreadsheet model for the above example in Appendix – B. This spreadsheet model uses Excel formulas to determine which machine processes the next job and also to calculate the completion times of each job.

Finally, we present Numerical Example 3. This example includes the due-dates of each of the jobs and the goal is to calculate job tardiness and the number of tardy jobs. Tardiness is an important measure of performance. Our students understand how late shipments from suppliers can negatively impact retailers in the case of highly seasonal products.

Numerical Example 3

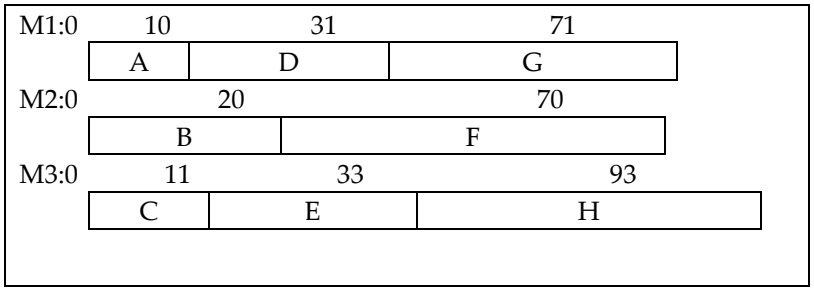
Consider *three* machines (M1, M2, M3) in parallel and a total of *eight* jobs (A, B, C, D, E, F, G, H). The jobs, their processing times (in hours) and due-dates (in hours) are as given below in Table 3. The goal is to reduce tardiness and number of tardy jobs. Intuitively, sequencing the jobs in non-increasing order of due-dates works well in terms of reducing tardiness and/or the number of tardy jobs.

TABLE 3

JOB	A	B	C	D	E	F	G	H
Processing Time (P)	10	20	11	21	22	50	40	60
Due-Date (D)	15	18	25	35	40	45	55	68

Since jobs are processed in the same order as in Example 2, the Gantt chart in Figure 3 is same as Figure 2.

FIGURE 3



Since we have only eight jobs in this example, it is easy to visually see what jobs are tardy. Note that Job A is done at t = 10 and is due only at t = 15. Hence, Job A is not tardy. Job B is done at t = 20 but is due at t = 18. Hence, Job B is tardy and its tardiness = 20 – 18 = 2 hours. Continuing in this fashion, we note that Jobs F, G, and H are also tardy by 25, 16, and 25 hours respectively.

A spreadsheet model with a detailed explanation is presented in Appendix – C. This spreadsheet goes beyond what was created in Appendix – B. So, we do not replicate what we already did in Appendix – B. We use NESTED IF functions to calculate when each job is completed on one of the three machines. Based on the due-date information, we use single IF statements to calculate job tardiness and the number of tardy jobs. Appendix C also includes Assignment 2 related to four parallel machines that the students must complete.

MANAGERIAL ISSUES

Flow shop models: Cutting and sewing are two important stages in apparel production. The shop floor supervisor may have to decide on worker and machine allocations on a daily basis since there can be several customer orders with different due-dates. The worker allocation also depends on the skillset i.e., some workers may specialize in men's clothing while others are experienced in cutting and sewing of women's or children's clothing. When there is sudden and unanticipated demand that needs to be fulfilled, the supervisor may have to consider overtime or hire temporary workers or rent additional machines or outsource some of the work. These are examples of some strategies that may need to be implemented frequently.

Parallel Machine models: As discussed earlier, we have assumed parallel machines to be identical machines. This is equivalent to check-out counters found in several retail outlets. The store manager must always make sure that the customer waiting lines are not very long. This is accomplished by opening one or more additional check-out counters during peak times and weekends. Having too many counters open is also not a good strategy. A good manager/supervisor is always trying to strike a balance between reducing customer wait times and minimizing the retail store's costs. Just like in the flow shop model, adding more machines, hiring more people, and outsourcing some work is commonly practiced.

In general, meeting customer deadlines is of utmost importance when it comes to apparel production. In the case of seasonal products, this importance increases exponentially. The supplier can lose a customer forever if a shipment is delayed.

CONCLUSION

Flow shop and parallel machine models typically find a place in engineering coursework. Most operations management textbooks used by business schools do not even cover parallel machine models. However, we have been able to successfully introduce these topics in a traditional fashion management class. The students were able to appreciate how these concepts are routinely used in the service industry as well as in the fashion and apparel industry. Furthermore, drawing Gannt charts to manually solve these problems enhances their understanding of the Math as they can visually see the entire

process. We then focus on these pictorial solutions to create spreadsheet models which enhance their understanding of Excel functions. Most students are then able to complete the two Assignments by putting in some effort. In conclusion, we believe that the students benefit from these topics because of their applications in the fashion field and also because of their enhanced understanding of the more complex Excel functions.

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APPENDIX – A: ***Excel based formulas for Numerical Example 1***

	A	B	C	D	E	F
1	JOB	M1	M2	M1Comp	Idle Time	M2Comp
2	B	20	25	20	20	45
3	A	35	40	55	10	95
4	E	36	45	91	0	140
5	C	38	50	129	0	190
6	D	40	20	169	0	210

The M1Comp and M2Comp columns calculate the completion times of the jobs on Machine 1 (M1) and Machine 2 (M2) respectively. The gray cells in the above spreadsheet contain the Excel formulas. However, the Excel formulas are written for Rows 2 and 3 only. Row 3 formulas are then copied down to the remaining rows for columns D and E until all jobs are sequenced. We also provide a detailed explanation below for each of these Excel formulas.

Excel formula for cell D2: Type "**=SUM(B$2:B2)**". This formula is then copied all the way down in column D. The rationale behind this formula being that M1 is never idle as long as there are jobs to be processed. Thus, the completion time of job B is 20 minutes, completion time of job A is 20 + 35 = 55 minutes and so on.

Excel formula for cell E2: Type "**=D2**". This formula calculates the initial Idle time. As we know from the Gantt chart in Figure 1, the initial Idle time on M2 is always equal to the 1st job's completion time on M1. Since Job B's completion time on M1 = 20, initial Idle Time on M2 is also equal to 20 minutes.

Excel formula for cell F2: Type "**=E2+C2**". This indicates that the 1st job's completion time on M2 = Initial Idle time on M2 + 1st job's processing time on M2. This is identical to the Gantt chart Math.

Excel formula for cell E3: Type "**=IF(D3>F2,D3-F2,0)**". From the Gantt chart, if the 2nd job's completion time on M1 > the 1st job's completion time on M2, then there will be Idle Time. This formula checks for that and also calculates the Idle time (the difference between those two values). If that condition is not satisfied, then Idle time = 0.

Excel formula for cell F3: Type "=F2+E3+C3". To verbalize this formula, the completion time of the 2nd job on M2 = Completion time of the 1st job on M2 + Idle time (if any) + the 2nd job's processing time on M2.

Now, Row 3 formulas in Columns E, F are copied down to the remaining rows until all jobs are processed.

Assignment 1: The original 4-machine problem (Pinedo, 2012) has been reduced to a 3-machine problem.

John has five jobs to be processed on three machines. The processing time values (in hours) on each of the three machines are given in Table 4 below. Determine the make span and find the total completion time of all jobs if sequenced in the same order in which it is given below i.e., A – B – C – D – E. *Submit a manual solution as well as an Excel based spreadsheet for this problem*.

TABLE 4

JOB	M1	M2	M3
A	5	4	4
B	5	4	4
C	3	2	3
D	6	4	4
E	3	4	1

APPENDIX – B: *Excel based formulas for Numerical Example 2*

	A	B	C	D	E	F
1	**JOB**	**P**	**M1**	**M2**	**M3**	
2	**A**	**10**	**10**	**20**	**11**	**JOBS A, B, C**
3	**B**	**20**	**31**	**20**	**11**	**JOB D**
4	**C**	**11**	**31**	**20**	**33**	**JOB E**
5	**D**	**21**	**31**	**70**	**33**	**JOB F**
6	**E**	**22**	**71**	**70**	**33**	**JOB G**
7	**F**	**50**	**71**	**70**	**93**	**JOB H**
8	**G**	**40**				
9	**H**	**60**				

The gray cells in the above spreadsheet contain the Excel formulas. However, we need to write Excel formulas for only Rows 2 and 3. Row 3 formulas are then copied down to the remaining rows until all jobs are sequenced.

Excel formulas for Row 2: Type "**=B2**", "**=B3**", "**=B4**" in cells C2, D2, and E2 respectively. This means we allocate Jobs A, B, C to M1, M2, M3 respectively. The numbers 10, 20, and 11 in cells C2, D2, and E2 indicate the completion times of Jobs A, B, and C.

Excel formulas for Row 3: In cell C3, type "**=IF(MIN($C2:$E2)=C2,C2+B5,C2)**". In simple terms, this formula allocates Job D (the 4th job) to the first available machine. Since the first available machine is M1 at time t = 10, Job D is allocated to M1.

In cell D3, type "**=IF(AND(MIN($C2:$E2)=D2,C3=C2),D2+B5,D2)**". This formula with the AND function allocates Job D to M2 only if it is not already allocated to M1. This is to break the ties if more than one machine is available at the same time. In this example, that is not the case. Hence, Job D is not allocated to M2.

In cell E3, type "**=IF(AND(MIN($C2:$E2)=E2,C3=C2,D3=D2),E2+B5,E2)**". This formula allocates Job D to M3 only if it is not already allocated to M1 or M2. This is to break the ties if more than one machine is available at the same time. In this example, that is not the case and hence Job D is not allocated to M3.

APPENDIX – C: ***Excel based formulas for Numerical Example 3***

	A	B	C	D	E	F	G	H	I	J
1	JOB	P	D	M1	M2	M3		COMP. TIME	TARDY?	TARDINESS
2	A	10	15	10	20	11	JOBS A, B, C	10	NO	0
3	B	20	18	31	20	11	JOB D	20	YES	2
4	C	11	25	31	20	33	JOB E	11	NO	0
5	D	21	35	31	70	33	JOB F	31	NO	0
6	E	22	40	71	70	33	JOB G	33	NO	0
7	F	50	45	71	70	93	JOB H	70	YES	25
8	G	40	55					71	YES	16
9	H	60	68					93	YES	25

The gray cells in the above spreadsheet contain the Excel formulas. Since we wrote Excel formulas for M1, M2, and M3 in Appendix B, we will not repeat those formulas here again. We will only focus on columns H, I, and J here.

Excel formulas for cells H2, H3, and H4: Type **"=D2", "=E2"** and **"=F2" respectively.**

Excel formula for cell H5: Type **"=IF(D3>D2,D3,(IF(E3>E2,E3,(IF(F3>F2,F3)))))**. This formula is then copied all the way down for Column H.

Excel formula for cell I2: Type **"=IF(H2>C2,"YES","NO")**. This formula is then copied all the way down for Column I.

Excel formula for cell J2: Type **"=IF(H2>C2,H2-C2,0)**. This formula is then copied all the way down for Column J.

Assignment 2

Consider *FOUR* machines (M1, M2, M3, M4) in parallel and a total of *eight* jobs (A, B, C, D, E, F, G, H). The jobs and their processing times (in minutes) are as given below in Table 5. The due-dates of these jobs are

also given. Use the due-date rule just like in Numerical Example 3 and calculate job tardiness and the number of tardy jobs. Since the data is identical to Numerical Example 3, the total job tardiness is expected to be significantly reduced with four machines. *Submit a manual solution as well as a spreadsheet model for this problem*.

TABLE 5

JOB	A	B	C	D	E	F	G	H
Processing Time (P)	10	20	11	21	22	50	40	60
Due-Date (D)	15	18	25	35	40	45	55	68