# Robotics, Automation and Intelligent Computing

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# PREFACE

The Research Association of Masters in Engineering is committed to providing a peer-reviewed platform to outstanding researchers to exhibit their findings for the furtherance of technology to provide a research forum. We are devoted to continual innovation to better support the wishes of our communities, making sure of the integrity of the research we publish, and championing the importance of open research.

ICRAIC 2K25: 3rd International Conference on Robotics, Automation and Intelligent Computing focused on the development and integration of robots, digitalization, automation, and AI technologies, inviting well-known experts and scholars at home and abroad, as well as scientific researchers and industry practitioners in the field of intelligent control, to jointly discuss the cutting-edge technologies of robots and their new applications in different industries, and build a robot innovation ecosystem. ICRAIC 2K25 aimed to showcase state-of-the-art methodologies and technologies in engineering and technology. It focused on new ideas and paves the way to disseminate the latest innovations and practices. It facilitates opportunities to network, collaborate, and exchange ideas with renowned leaders, scientists, and researchers in robotics, automation and intelligent computing. It acts as a crucial platform for industry and academia to foster innovative ideas, theories, frameworks, and applications. ICRAIC 2K25 has encouraged recent and futuristic advancements, challenges, and new strategies in the frontiers of robotics, automation and intelligent computing.

Dr. Rakesh Himte, Principal, Vidyavardhini's College of Engineering & Technology, Vasai, Maharashra, India was the Chief Guest of the conference and delivered an inaugural address. Dr. Rudrarup Gupta, Faculty, Tagore School of Rural Development and Agriculture Management, University of Kalyani, Kalyani, India. Several students/ research scholars and academicians have presented their research work at ICRAIC 2K25 in the areas of robotics, automation in production, intelligent computing and artificial intelligence. We believe that the knowledge exchanged at ICRAIC 2K25 immensely helps the researchers working in relevant fields and contributes to the growth of science and technology.

Taking into account the various circumstances of the participants after COVID-19, ICRAIC adopted all available social media methods, such as online/video presentation, amongst other methods, besides the regular

presentation styles (oral & poster). The online/video presentation session was arranged via ZOOM platform. Authors participated through online presentation and connected at the time of their session on an online platform. Our sincere thanks to the keynote speakers, reviewers, technical and advisory committee members, organizing committee, and all authors for their contribution in making ICRAIC 2K25 a grand success.

# CHAPTER 1

# THE CRITICAL INFLUENCE OF LEADERSHIP ON ORGANIZATIONAL SUCCESSION PLANNING

DR. RUDRARUP GUPTA

## Abstract

Empowerment of "Thoughtful Leaders" is a most significant incorporation of an organization from the perspective of its lively infrastructural base. Most notably, this term "Organization" is based upon a number of functional brains and the matured cognitive reflections at the same point of time. That is why leaders try to arrange for a substantial amount of money to strengthen "Business capital" and, on the other hand, they are equally concerned about empowering the most methodical resources to ensure their constructive commercial beginning, which is undoubtedly very healthy, not purely to establish their productive benevolence in the end. Leaders are well versed in carrying their collective frame of mind with everlasting determination for "Successful Resource Empowerment" to initiate their constructive business planning and its powerful capitalization in all regards. The prime motive is to survive in embarking on the existing occupational virtuoso, which would definitely be unbeaten and unforgettable in nature. This is how all the diligent associates will be deliberately empowered, along with their never-ending devotion to explore their collective occupational resilience to opt for business as much as possible; which is related with their much-anticipated sustainability. In other words, any communal harmony in an organization is highly successful once the loop of communication is absolutely up to the mark. Therefore, promising integrity, cultural diversity and invariable organizational unity are really essential for both leaders and followers to snatch favorable outcomes in the end.

**Keywords:** a. Proactive occupational resilience, b. significant initiatives of leaders, c. distinctive cooperation of leaders, d. meticulous organizational

elevation, e. proper implementation of cognitive thoughts, f. successful functionality of an organization.

## 1. Introduction

The establishment of any organization largely depends upon the legal papers but the compelling future of an organization is truly based upon the authentic employees /followers. So, the foremost assignment of a neat and clean follower should be to understand what exactly an organization is looking at and what exactly he/she is desirous to provide. Now the parity between the organizational demand and the desire of followers must be matched right from day one. It shall be really engaging from the perspective of followers to realize the needful organizational steps and, from the end of the organization it will definitely be in a different shape, not only as an exclusive example but also well recorded to hold the global business goodwill as well.

Therefore, once the leaders do complete their fundamental training, followers shall have to abide by the following:

1. **Stable Locality:** Followers shall have to understand the exact location and they shall have to study the class of people in that very region. So, they will be able to generate an additional perception in approaching their products in a very tactful strategy of mutual understanding. Organizational representatives shall have to be very natural, honest and prompt in ensuring the bona fide products and consequential future of an organization. This is how the mutual trust will be definitely built up and both the sides will be equally in the same equation to proceed further.
2. **Real Conceptual Depth:** My perception says each of the followers shall have to be absolutely prepared to express their extensive knowledge about the product in such a manner so as to draw the best attention of their oppositions. Because, according to the present-day scenario, people do not have sufficient time and concentrate on the most beneficial glimpse of all. All the customers should be satisfied by purchasing and utilizing their products in their various needs.
3. **Pivotal Fortitude:** It is very important indeed because this exclusive attribute may change the entire scenario in the end. Marketing personnel shall have to have high-end patience until that very product is significantly conceptualized. The best professional dealing will be successful when both marketing personnel and their clients are close to the anticipated breakeven. Otherwise, the entire efforts will be

completely lost and the furtherance of that discussion will not be matured in the future.

4. **Cognitive Disclosure:** Marketing executives will have to be very watchful and shall have to have exceptional intelligence at all times. It shall be really very conducive for them to estimate the mind frame of their clients. It requires long, firm conversations with impactful logic and mutual understanding, respectively. It shall be easier for marketing executives to have a greater number of clients for their anticipated business revenue.
5. **Graceful Aspect:** Marketing executives need such an appearance to meet their business clients from any class. It shall determine their most valuable presence and that very appearance shall be full of zeal, ardent interest and bottomless cognition at the end of the day. It matters not only to convince someone who is listening to our thoughts and product designs, but the most affable impression will be created for that representative and the goodwill of that organization will remain.
6. **Sound Psychological Depth:** It is really very helpful because it provides the additional affluence to the approach of the business and it is going to be really successful if the marketing executive has the vigor to sell the product along with the most affluent knowledge of the product, which has the invariable mileage for the client to do the same.
7. **Powerful Regularity:** Business is a vast chapter with very rational protocols which are regulated by both leaders and their subordinates. Each member of an organization shall have to be very consistent in enriching the relevant business good will and the innovative ideologies of products. This is how the conception of that product will be disseminated very comprehensively. Consistency of performance and holding the organizational caliber are very important and these should be established according to the gradual modification of an organization.
8. **Decisive Awareness:** It is another most essential attribute. Because without this the radiance or organizational growth will be not possible and, on the other hand, leaders and followers will not be able to understand the profitable dimension of that organization and the entire strategy will be completely in vain.

Ruth, Massis, Reccardo and Silvio (2024, 1-36) stated that “Human-Resources” is one of the major portions of an organization. Most notably, most organizations sustain through progressive technology in the end.

## 2. Materials and Methods

In this regard, it is quite evident that good marketing strategy needs a sound literature review and conceptual organizational literature. On the other hand, if the organizational literature is really reflective, then the product will automatically be designed accordingly.

Therefore, the entire managerial hierarchy needs the 5 tenets of life, which are absolutely required to refine the strategy according to the best needs of industry and society as a whole. That is why both leaders and followers should be following the information given below:

1. **Own Conviction:** It is really pivotal once the organizational functions are regulated and leaders segregate the entire work force amongst their followers as per the respective departments. It brings out the energy and arbitration to analyze the product and find appropriate conception in the end. As a result, they are truly upright, not only to memorize the utmost implications of that product but to implement their illustrious impression at the same time.
2. **Reliance of Personality:** They must be concerned about their capacities and the hard course of work. In this regard, their visions will be much sharper and they will be involved with absolute business dealing every now and then.
3. **Directional Identity:** Both leaders and followers shall be well disciplined not only to run the legitimate organizational paradigm but to motivate their entire managerial hierarchy. So the product of knowledge and the exclusive exploration of business will unquestionably flourish in a very conforming manner.
4. **Estimation of Oneself:** Each leader and follower should have absolute self esteem and that shall have to be properly focused at the time of inclining occupational involvements where all successful business dealings are undoubtedly connected along with ravishing financial standing.
5. **Performance Appraisal:** Leaders and followers should assess their present occupational contributions and they have to change alongside their most sincere practices. Dedicated practices ensure the solution. They shall have to maintain the same in all regards. Without any positive assessment, not a single output will be taking place and the business strategy will be on the back foot. Therefore, both leaders and followers shall have to concentrate upon the same, not only to save the organization from any of the unavoidable resilience, but to generate extensive financial revenue.

**Own Vision:** It is indeed very crucial not only to drive the meticulous functions of an organization but to proceed based upon the targets. This is how veteran leaders give an oath for an organization to reach its pre-anticipated destiny along with their formularization of commercial proceedings.

Ganesh and R Pagare's (2024, 1-7) "Service Quality Management" is one of the significant avenues for "Organizational Success" in service industries. It firmly influences customer satisfaction, loyalty and employee performance respectively.

## 3. Results and discussions

a. **Positive Ingenuity:** Leaders should inspire their followers not only to understand the products thoroughly but to implement their IQ at the same time as successful business dealing. Moreover, both their mental and physical makeup will be really advanced and they will be able to proceed along with their indomitable spirits.
b. **Natural Inducement:** Leaders have to motivate their immediate followers and it shall be both intrinsic and extrinsic in nature. Intrinsic means gradual promotions, as per performance, and extrinsic motivations include fame, rewards, money etc. That is how the highest volume of business will be definitely secured from their point of view.
c. **Consultative Planning:** It is important for them to make up their mind and intellect of exclusive need and in this regard all leaders understand their impulsive stand and assign tasks accordingly.
d. **Eye on Action:** Followers need to be monitored for their prompt refinements and their all-round spirits to drive the entire organization without any second thought. That is how leaders are able to enhance both the cash flow and fund flow of their organization.
e. **Industrial Assessments:** Followers should be into different experiments through various pilot projects, different analytical reviews and so on. It is the remedy to estimate their present qualitative measures.

**Authoritative Proclamation:** Leaders are really the best resource to inspire their employees to understand the individual nature of their job. It is undoubtedly required for all of them to concentrate upon the work to ensure the supreme organizational outcome with clarity.

Vaisali and Manya's (2023, 1-11) "Manuscript" signifies that about all the technology-regulated organizations are largely dependent upon "Human-Resources" of any organization. The prime reflection is that a

lively technological progress is truly ensured and enriched by the "Technological Human Brains".

1. Administrative Perspective:

a. **Consideration of Official Documents:** It needs to be taken care of and the entire managerial hierarchy should be under this evaluation. Most notably, all the leaders shall have to look after this and they shall have to approve the venture accordingly.
b. **Professional Succession:** Both departmental heads and leaders are equally responsible for this elevation through their approved business strategies. In this regard, both leaders and followers shall have to be really decisive to enable dissemination of the ratio of profit.
c. **Managerial Tranquility:** It shall have to be maintained because it is a matter of great occupational bonding and in this regard, both leaders and followers shall have to work along with their ageless understanding, collective competency and inextinguishable values.
d. **Enthusiastic Alert:** Each department should have their anticipated depth and the allotted nature of responsibilities. They shall grow as per their invariable individuality. As a result, conflicts will not take place and individual advancement will be achieved.
e. **Genuine Contemplation:** Both leaders and followers shall adopt the same strategy and plan so that they will be enriched in the same platform of collective proclamation and communal harmony will be formed; substantial magnificence of an organization will be achieved in style.

Zulkifli and Dr. Pooja (2024, 1064-1074) clearly manifested that "Strategic Human Resource Management Practices" are truly imperative for refining "Organizational Performance" in rapidly changing environments, in an existing position of the "Fast Changing Business World".

2. Individual Perspective:

a. **Purity of Commendation:** Each leader and follower has to invariably admire each other for the inclining volume of hard work and that is how the formal balance will take place between leaders and followers so their best consequential future will be secured.
b. **Noticeable Reflection:** Leaders shall have to consider the happenings through their formal justifications, because it is a passive inspiration and that is how they shall be able to hold the professional community

in the end and, as a result, the formulation of that business will be truly reformed.

c. **Effective Promulgation:** Leaders shall have to disseminate all the inspiring thoughts or newly invented introspections to all on a platform of mass learning and that shall be undoubtedly utilized in confirming successful occupational acceleration.
d. **Pre-scheduled Accomplishment:** It is essential for the authority or leaders to inculcate new thinking and innovative brains to promulgate the approved strategy, something which should be theorized in the end.
e. **Sensitivity of Verdict:** It should be straight, prompt and target-oriented in nature. Most notably, the entire organizational shape shall be modified and the decisions from followers and leaders shall have to be clubbed together to find the best collective solution where the "participative leadership approach" is enforced.

Therefore,

1. Market research is needed for prompt initiative.
2. Prompt initiative is needed for concrete planning.
3. Concrete planning is needed for scheduled execution.
4. Scheduled execution is needed for stunning occupational acceleration.
5. Occupational acceleration is needed for successful business strategy.
6. Business strategy is needed for reflective proceedings.
7. Reflective proceedings are needed for determining navigation.
8. Determining navigation is needed for robust occupational depiction.
9. Robust occupational depiction is needed for destined organizational goals.
10. Destined organizational goals are needed for the "Historic Organizational Vertex".

A. Murphy (2024, 26-33) successfully examined multifarious aspects of employee well-being, which is comprised in both dividable and global perspectives, respectively.

## 4. Veteran leaders and their enriching turn of minds

"Commercial Likelihood" is one of the riveting organizational affairs so it needs exclusive brain storming and leaders to bring out such possibilities in the near future, which are absolutely imperative for both leaders and followers to adopt to find the best solution. The solution is having outstanding future outcomes and that shall undoubtedly enrich our great economical growth shortly.

a. **Phenomenal Origination:** Each leader shall have to be really innovative and they shall have to find out the fundamental cause of commercial enhancement and the prosperous culmination through the magnificent implementation of technology.
b. **Distinct Equitability:** The real focus largely depends upon communal objectivity. In this regard, all the leaders shall have to build the invariable community where they can have ingenious support and assistance from their followers, so that they shall be able to ensure their impactful developmental objectivity in style.
c. **Anticipated Attainability:** It is indeed very imperative from the perspective of organizational shine that each leader must have a practical core and lead the organization using their core vision and worthy mission at the same time.
d. **Workable Rapidity:** It means a lot. The paradigm of an organization shall have to be absolutely amicable and it should definitely be convincing and praiseworthy at the same time. Leaders have to take the smart initiative to make it happen and they shall have to adjust their strategies accordingly.
e. **Purposeful Coherence:** Organizational leaders need the same, otherwise they shall not be able to go in depth and the progressive clarity will not be reflected at all. As a result, their entire managerial hierarchy will be undoubtedly stimulated to work hard and the entire planning will be under a genuine guidance where leaders are the most proficient resource to make it truly possible.

Mansi and Prof. Nita (2024, 1594-1598) studied the exclusive effects on "Human Relations upon Organizational Productivity" in a cut-throat business environment.

## 5. The perceptual envision

The concept of "Business Strategy" is one of the significant commercial practices which are to be magnificently regulated by both leaders and followers to enrich the pre-scheduled organizational objectives in connection with our best occupational sustainability along with the viable celerity of commerce from the perspective of both words and wisdom. In this regard, leaders shall have to find the most concrete avenue to work along with their competent team members to accomplish the desired organizational goal based upon their collective initiatives and participations. It is really a core drawing of a concrete plan where every individual of that organization shall have to understand the present stature

of a company and what should be done in enriching the satisfactory volume of business and the remarkable organizational growth respectively. That is why some leaders speculate about brand new inventions and their respective implementations. They must be associated with the organization so as to search for profound avenues, not only for substantial money but to connect with a number of sound ventures, which might be flourished in the long run. Therefore, each industry will have the glorious hope of generating money and they will be able to secure such amount of money, which is undoubtedly imperative for surviving in terms of finance, global acceptance and goodwill. First of all, business strategy needs bold manpower, who will be truly responsible for searching the market, finding the most lucid equation to instigate a formal bonding. The concept of global network is one of the crucial factors here to initiate significant business dealings and it is really consequentially effective in nature. In this regard, the gracious managerial hierarchy shall have to be ensured where the minute evaluation is undoubtedly required, according to their qualification, age, desire, exposure, qualitative measure, network, perception, understanding and most notably, their professional foresight.

Danial, Mohd and Zainal (2024, 1-19) significantly identified different "Human Capital Development Techniques" for healthy "Work Performance Developments" in the promising "Engineering Industry".

## 6. Conclusions

The entire business strategy will have to be unique and easily understandable for the entire managerial hierarchy, so that it shall be practically absorbed by people right from the top to the lower levels. These people will contribute their best to bring out the histrionic occupational virtuoso within the stipulated time frame, offering famed broadcasting all over the globe, and sustaining their proclaimed inventive paradigm. Once all the said parameters are completely dealt with, then the process of recruitment might be initiated and all the candidates shall have to fulfill all the criteria and express their mutual reflection of mind as per the promise and commitments. It will be comparatively easier for them to instigate their professional operation and this is how the business strategy will be much developed.

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# CHAPTER 2

# ADVANCEMENT IN WASTE MANAGEMENT: A SURVEY ON DETECTION, CLASSIFICATION AND ROBOTIC SYSTEMS

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## Abstract

Effective waste management plays a crucial role in promoting environmental sustainability and safeguarding public health by systematically collecting, processing, and disposing of waste. Presently, the systems of waste management face a lot of challenges, particularly inefficiency in segregating waste, inadequate recycling facilities, and improper disposal techniques, which result in the pollution of the environment and depletion of resources. One of the major drawbacks is over-reliance on manual processes, which leads to errors, increased operational costs, and health risks to workers. Lack of public awareness and inadequate infrastructure further worsen the situation, making waste management less effective in many regions. The increasing volume of waste due to rapid urbanization and population growth further puts pressure on existing systems. To address these problems, automation and smart technologies can transform waste management with increased efficiency, proper waste segregation, and reduced human intervention. Such developments can potentially provide a more sustainable and streamlined approach to waste management.

**Keywords:** YOLO v8, Real time detection and classification, segregation

# 1. Introduction

Efficient management of resources has become a critical focus in addressing global environmental concerns. With the rapid pace of urbanization and industrialization, the need for innovative approaches to handle increasing waste volumes has never been more pressing. Modern methodologies now integrate artificial intelligence, machine learning, and robotics to automate processes, reducing human intervention and enhancing precision. These technologies rely on well-curated datasets and advanced algorithms to adapt to diverse conditions and environments, enabling scalable solutions. By bridging technological advancements with sustainable practices, researchers aim to create systems that not only improve efficiency but also contribute significantly to reducing environmental pollution and resource wastage.

In waste detection, algorithms for object identification such as YOLO (You Only Look Once) have proven to be transformative due to their real-time accuracy and computational efficiency. Among its variants, YOLOv5 has been extensively used for outdoor trash detection, employing large-scale datasets derived from sources like Openlittermap and public areas in regions such as Bangladesh. To further enhance its robustness, researchers use sophisticated data augmentation techniques, including hue shift, scaling, flipping, and mixup, creating diverse training datasets that mimic real-world conditions. YOLOv5x, a more advanced variant from the family of YOLO algorithms, has demonstrated exceptional performance, achieving high mean Average Precision (mAP) scores in experimental evaluations. This underscores its capability to identify and classify different waste types, even in challenging environments, contributing to real life application for waste management. Significant advancements have been witnessed in waste sorting systems that have a critical part in recycling and resource recovery. For instance, MobileNetV3, a lightweight convolutional neural network, has been enhanced to address garbage classification tasks. Techniques like transfer learning, which utilizes pre-trained models, and the integration of attention modules like CBAM (Convolutional Block Attention Module) helps the model to learn the most relevant features of the given data. This approach, combined with diverse datasets featuring thousands of annotated images, ensures high classification accuracy. An improved version of MobileNetV3, tailored for deployment on resource-constrained devices, has achieved recognition accuracies of over 96% while maintaining a low parameter count and rapid inference times. These attributes make such models particularly suitable for embedded systems in urban waste management infrastructures.

Robotic automation has revolutionized the path planning and sorting aspects of waste management by introducing precision and speed into the process. Systems equipped with advanced algorithms like YOLOv6 and YOLOv8 have demonstrated remarkable efficiency in classifying and segregating waste materials. By leveraging datasets like the modified TrashNet and Garbage Classification Dataset, these systems achieve enhanced precision and recall rates, ensuring minimal misclassifications. Integrated into robotic arms or mobile platforms, these models enable real-time sorting and segregation with low latency, even in dynamic and unstructured environments. The adaptability of such robotic systems to navigate, detect, and sort waste autonomously has opened new possibilities for smart waste management, particularly in urban and industrial scenarios where manual processes are inefficient and time-consuming.

These technological advancements in waste detection, sorting, and path planning represent the confluence of AI, robotics, and environmental sustainability. With ongoing research, there is an increasing focus on improving the scalability, adaptability, and reliability of these systems to address global waste challenges comprehensively. As these solutions continue to evolve, they promise to pave the way for a cleaner, more sustainable future, contributing significantly to resource conservation and environmental protection.

## 2. Literature Survey

**Das, Deb, Sayeed, Dhar and Shimamura (2023, 3)** present a comprehensive study on outdoor trash detection, addressing the pressing issue of improper waste disposal and its environmental impacts. The authors employed the YOLOv5 algorithm, a state-of-the-art object detection model known for its efficiency and accuracy, making it ideal for real-life instances in waste management. To enhance the model's performance, they created a dataset consisting of 1,283 images of trash collected from various public spaces in Bangladesh, which included ten distinct trash categories. This dataset was further augmented by integrating data from Openlittermap, resulting in a total of 4,418 images with 9,837 annotations, allowing the model to generalize better across different trash types and environments.

The approach utilized various methods for augmenting data to enlarge the training dataset and enhance the model's adaptability to real-world variations. Techniques such as hue shift, saturation shift, value shift, translation, scaling, flipping, mosaic, and mixup were employed to create novel variants of existing images, thereby enhancing the model's ability to detect trash under diverse conditions. The authors conducted extensive

experiments with different YOLOv5 variants (YOLOv5s, YOLOv5m, YOLOv5l, and YOLOv5x) and evaluated their performance using mean Average Precision (mAP) metrics at various Intersection over Union (IoU) thresholds.

The results indicated that the YOLOv5x model achieved the highest mAP of 33.3% at an IoU of 50, outperforming other state-of-the-art models in the domain of trash detection. This performance underscores the effectiveness of the proposed approach in addressing the challenges of outdoor trash detection, ultimately contributing to improved waste management strategies and environmental conservation efforts. The study highlights the importance of public awareness regarding proper waste disposal and the need for effective waste management systems, particularly in regions with limited resources.

**Tian, Shi, Luo and Zhang (2024, 4)** introduced a novel garbage classification algorithm leveraging an enhanced MobileNetV3 architecture, specifically designed to address the growing need for efficient waste management solutions. As urbanization increases, the challenge of effective garbage classification becomes paramount, necessitating the development of lightweight models that can operate on embedded devices with limited computational resources. The authors aim to enhance the MobileNetV3 model by integrating advanced techniques like transfer learning, enabling the model to utilize pre-trained weights from extensive datasets. This approach accelerates training and boosts accuracy.

In terms of methodology, the study employs data augmentation strategies to artificially expand the dataset, enhancing the model's ability to generalize across various garbage types. The integration of the Convolutional Block Attention Module (CBAM) is a significant innovation, as it enables the model to focus on the most relevant features of the input images, thereby improving classification performance. Additionally, the Mish activation function is utilized to enhance the model's non-linearity, which contributes to better learning dynamics and overall performance. The use of global average pooling further reduces the model's complexity by minimizing the number of parameters, which is crucial for deployment on resource-constrained devices.

The dataset used in this research is a meticulously curated collection of 4152 images, specifically tailored for garbage classification tasks. This dataset was developed through a combination of online image retrieval and real-world photography, ensuring a diverse representation of various waste types. The authors highlight the inadequacies of existing datasets, such as TrashNet, which do not sufficiently cover the complexities of real-world garbage classification scenarios.

Performance metrics indicate that the improved GMC-MobileNetV3 model achieves an impressive recognition accuracy of 96.55%, showcasing its effectiveness in accurately classifying different types of waste. With a parameter count of only 0.64M, the model remains lightweight, making it suitable for deployment on mobile and embedded devices. Furthermore, the model demonstrates a rapid detection time of 26.4ms per image, which is critical for real-time applications. The results indicate that the improved model not only surpasses the performance of other mainstream algorithms but also exhibits enhanced stability and lower loss rates during training, positioning it as a viable solution for practical garbage classification applications in smart waste management systems. Overall, this research contributes significantly to the field of computer vision and environmental sustainability by providing an efficient and effective tool for waste classification.

**Ibrahim, Shoitan, Moussa, Elnemr, Cho and Abdallah (2023, 5)** introduced an automated segregation system for waste which is innovative and also leverages a robotic arm and the YOLOv6 object detection algorithm to enhance the efficiency of waste management processes. The primary objective is to develop a solution that can accurately classify and segregate various types of waste in real-time, thereby reducing human intervention and improving recycling rates. The methodology begins with the selection of YOLOv6 model, known for the speed and accuracy in object detection tasks, which is fine-tuned to adapt to the specific requirements of waste classification.

The dataset utilized for carrying out this work was an enhanced edition of the TrashNet dataset, which comprises 3,217 images categorized into seven distinct classes: cardboard, glass, metal, paper, plastic, battery, and foam. To improve the model's robustness, data augmentation techniques such as rotation, scaling, and flipping were applied, resulting in a more diverse training set that enhances the model's ability to generalize across different waste types. The training process involved multiple runs, with the model's performance evaluated based on key metrics including precision, recall, and F1 score.

The results of the experiments were promising, with YOLOv6 achieving a precision of 96.47%, recall of 94.89%, and an F1 score of 95.67% in the third training run. These metrics indicate a high level of accuracy in detecting and classifying waste items, demonstrating the model's effectiveness compared to other object detection frameworks like YOLOv7 and YOLOR. Additionally, the system's low inference time allows for real-time processing, making it suitable for practical applications in smart waste management systems. The paper concludes with a discussion on future

work, which includes expanding the dataset further and implementing the developed system in real-world scenarios to validate its performance and scalability in urban waste management contexts.

**Azfar, Rastari, Roslan, Hamzah, Teo, Shahbudin and Samah (2024, 5-6)** explore the pressing need for efficient waste management solutions, particularly in urban areas where the volume of recyclable waste continues to rise. To address this challenge, the authors developed a sophisticated model based on the YOLO Version 8 algorithm, which is renowned for its speed and accuracy in object detection tasks. The study meticulously details the methodology, beginning with the collection of a diverse dataset comprising 10,057 images from Malacca and Selangor, alongside additional data from the Garbage Classification Dataset. This dataset was carefully curated to ensure a balanced representation of the four targeted recyclable materials: paper, glass, metal, and plastic.

In the pre-processing phase, the authors applied techniques such as data resizing and augmentation to enhance the robustness of the model, allowing it to generalize better across various conditions and lighting scenarios. The model was then trained and tested using both random-splitting and manual-splitting approaches to validate its performance comprehensively. The evaluation metrics employed included accuracy, precision, recall, and F1-score, which are critical for assessing the model's effectiveness in real-world applications.

The results were promising, with the YOLO-v8 model achieving an accuracy of 97.63%, precision of 95.3%, recall of 93.03%, and an F1-score of 97.63%. These metrics indicate not only the model's high detection capability but also its reliability in minimizing false positives and negatives, which are crucial for practical deployment in waste management systems. The authors emphasize the significance of their findings, suggesting that the model can significantly enhance the efficiency of waste sorting processes and reduce contamination rates in recycling streams, thus leading to sustainability. Furthermore, the adaptability of the YOLO-v8 model opens avenues for future research, allowing for the inclusion of additional waste types and the potential integration of the model into smart waste management systems, thereby fostering a cleaner and more sustainable environment.

**Kiyokawa, Katayama, Tatsuta, Takamatsu and Ogasawara (2021, 6-7)** introduce a holistic approach to improving waste detection by utilizing a robotic system for training dataset collection, incorporating advanced image adaptation techniques. By employing histogram matching, the system ensures consistent lighting across images, which is critical for accurate object recognition. Background synthesis adds variability to the

dataset, simulating different environments where waste might be found, while object scaling allows the model to learn from images of waste items at various sizes, improving its robustness and generalization capabilities.

The convolutional neural network (CNN) architecture used for the waste detection model is specifically designed to handle the complexities of image data, enabling it to learn intricate patterns associated with different types of waste. The extensive dataset of 59,400 images, collected in a rapid and automated manner, provides a rich source of training data that enhances the model's ability to detect and classify waste accurately. This dataset not only accelerates the training process but also ensures that the model is exposed to a wide range of scenarios, which is essential for real-world applications.

Performance metrics indicate that the waste detector achieved a mean F-score of approximately 46%, reflecting a commendable balance between precision (the accuracy of positive predictions) and recall (the ability to identify all relevant instances). The model's accuracy surpassed that of traditional methods that did not incorporate the advanced adaptation techniques, demonstrating the effectiveness of the proposed system. In practical applications, the robotic waste-sorting system achieved a manipulation success rate exceeding 61%, with the push-and-drop method being notably more efficient than the pick-and-release method by 1.9 seconds. This efficiency not only underscores the model's effectiveness in real-time waste detection but also highlights its potential for integration into automated waste management systems, ultimately contributing to enhanced recycling efforts and environmental sustainability. The findings suggest that such robotic systems could play a pivotal role in addressing the challenges of waste management in urban environments, promoting cleaner cities and more efficient resource recovery.

**Flores, Dauz, Calica, De Guzman, Ganuelas, Olbinado and Ventura (2023, 7)** explores the pressing need for efficient waste management systems, particularly in urban areas where improper disposal and unsegregated trash pose significant health and environmental risks. Addressing these challenges, the authors developed a smart trash bin system that integrates Arduino microcontrollers, capacitive and inductive proximity sensors, ultrasonic sensors, and GSM communication. This innovative approach aims to enhance waste segregation and facilitate efficient waste collection through real-time trash level monitoring and automated notifications to authorities. Furthermore, the system is powered by a solar panel to ensure sustainability and energy efficiency.

In the pre-processing phase, the study leveraged capacitive and inductive sensors to detect and classify recyclable materials accurately. The capacitive sensors determine the presence of objects, while inductive

sensors identify metallic items. This dual-sensor mechanism ensures precise categorization into metal and non-metal waste bins. Additionally, the system's ultrasonic sensor monitors trash levels, ensuring timely notifications through GSM when bins are nearly full. The pre-processing was further enhanced by calibrating sensor placements to maximize detection accuracy and adjusting servo motor mechanisms for seamless lid operations.

The results demonstrated that the smart trash bin effectively segregated recyclable materials and provided accurate trash level detection. The system reliably sent SMS alerts for full bins and showcased robust functionality during hardware testing. However, minor issues, such as signal strength affecting GSM performance, were observed, which the researchers addressed by optimizing placement and network selection. The system's affordability, costing $180, makes it a competitive and accessible solution compared to existing smart bins.

**Wulandari, Ariwibowo, Taryo and Ananda (2024, 7-8)** explore the necessity of efficient waste management systems, particularly focusing on automating the segregation of metal and non-metal waste. To address this challenge, the authors designed a smart trash system leveraging inductive proximity sensors and ultrasonic sensors, controlled by an Arduino Uno microcontroller. The system employs a conveyor mechanism to facilitate waste transport and sorting, ensuring accurate categorization and efficient disposal. This innovation not only aims to reduce human intervention in waste segregation but also supports environmental sustainability in urban waste management practices.

In the pre-processing phase, the smart trash system detects waste within a diameter of 15 cm using ultrasonic sensors, and sorted by stopping for 0.5 seconds. Inductive proximity sensors identify waste type at a 2 cm distance. Depending on the detection, the servo motor moves 30 degrees either to the right for metal waste or to the left for non-metal waste. The calibrated sensor setup and servo movements ensure precise segregation, significantly enhancing the system’s reliability and operational efficiency.

The results highlight the effectiveness of the system, with the ultrasonic sensor accurately detecting various objects at the specified distance, halting the conveyor as designed. The proximity sensor successfully identified metal and non-metal waste with high precision, enabling accurate sorting via servo motor movements. The mechanical design, which includes a 1-meter conveyor operated by a stepper motor, demonstrated robust performance during trials.

**Winarno, Ilham and Mulianto (2024, 8)** explore an Arduino Uno-driven process for segregating metal and non-metal waste, aiming to

enhance recycling processes and reduce environmental pollution. The system utilizes proximity sensors for waste detection, servo motors for sorting, and an LCD for displaying waste types. This innovative approach automates waste management, streamlining the segregation process and promoting sustainable practices, especially in urban areas.

In the pre-processing phase, the system employs ultrasonic (HCSR04) sensors to detect the presence of waste. These sensors accurately identify objects within a range of 0–1 cm for metal and classify non-metal objects beyond this distance. Proximity sensors determine the type of waste, signaling the servo motor to rotate 90 degrees either left for non-metal or right for metal. The system's compact design includes two separate bins for metal and non-metal waste, ensuring effective segregation.

The results indicate high system reliability in real-world testing. The ultrasonic sensors consistently detected waste within the specified range, while the proximity sensors demonstrated a 95% accuracy in distinguishing between metal and non-metal waste. The sorting mechanism, driven by servo motors, successfully directed waste to the appropriate bins with a response time of 6 seconds.

**Ali, CHVS, Teja, Jyothi and Kuma (2024, 8-9)** explore the development of an intelligent waste sorting system utilizing the YOLOv5x deep learning model and Arduino integration to address challenges in waste management. The system automates the detection and classification of waste into predefined categories such as plastic, metal, glass, paper, and others. The research emphasizes YOLOv5x's efficiency for real-time object detection, while Arduino facilitates physical sorting actions. The study outlines a holistic approach, combining neural network-based object recognition with hardware implementations to streamline waste management processes, reducing reliance on manual labor and increasing sorting accuracy.

The proposed methodology involves creating a balanced dataset of 4,745 training images and 457 validation images, labeled across seven waste classes. The YOLOv5x model architecture includes CSPDarkNet53 as the backbone for feature extraction, an enhanced Path Aggregation Network (PANet) for feature fusion, and a detection head for generating predictions. The model undergoes hyperparameter tuning to optimize its performance, while Arduino integration automates waste segregation into collector pits based on detection outcomes. This system is designed for adaptability in various applications, from smart bins to industrial-scale facilities.

The results indicate that the YOLOv5x model achieved an impressive detection accuracy of 95.67%, outperforming earlier YOLO versions and other benchmarks. This high accuracy underscores its potential for scalable

and real-time waste management applications. The study utilized a custom dataset for training and validation, ensuring robust classification across diverse waste types. This combination of advanced AI techniques and hardware innovation demonstrates significant promise in addressing global waste management challenges.

**Lahoti, Sn, Krishna, Prasad, B.S, Mysore and Nayak (2024, 9-10)** explore the development of a multi-class waste segregation system combining computer vision and robotics. The proposed system employs the YOLOv5 object detection model and a 3D-printed robotic arm with five degrees of freedom (DOF) to automate the classification and sorting of recyclable waste. Categories such as paper, plastic, metal, glass, cardboard, and biodegradable materials are detected using annotated datasets, with the YOLOv5 model performing real-time classification. The robotic arm, integrated via an Arduino controller, handles the physical segregation, placing waste items into designated bins based on their classifications. The system's emphasis on automation addresses the environmental and operational challenges of traditional manual sorting.

The methodology incorporates the YOLOv5 model trained on a custom dataset of 10,464 images spanning six waste categories. This dataset, sourced from Roboflow, features bounding box annotations for precise object detection. Image frames captured via a webcam are processed in real time, and the classified outputs are transmitted to the robotic arm for action through a Raspberry Pi and Arduino interface. The robotic arm, constructed using lightweight 3D-printed materials, utilizes servo motors for precise movements, ensuring accurate waste placement. The integrated system is tested in controlled environments to evaluate its performance in categorizing and segregating various types of household waste.

The results highlight an average accuracy of 80% for waste segregation, with the YOLOv5 model achieving a precision of 0.65 and recall of 0.50. Classification challenges were observed for thin and flat materials like paper, but glass and metal categories demonstrated high precision, with the glass achieving a precision rate of 0.92. To improve robustness, further dataset expansion and extended training epochs were suggested.

**Okomba, Abidemi, Chikezie, Nwobodo and Nduanya (2024, 10)** explore the development of a home-applied waste segregation and management system utilizing IoT technology to address inefficiencies in household waste management. The system classifies waste into three categories: wet, dry, and metallic. Waste is deposited onto a mechanical flap that directs it into designated bins based on sensor data. A rain sensor detects moisture content to identify wet and dry waste, while a photoelectric metal sensor prioritizes metallic waste. Ultrasonic sensors measure waste levels

within the bins, triggering notifications to waste management personnel when thresholds are reached. The system is integrated with a WhatsApp chatbot via a Wi-Fi module, enabling real-time updates to ensure efficient waste disposal.

The methodology involves the integration of hardware components, including Node MCU as the central microcontroller, ultrasonic sensors to detect user approach and waste levels, a rain sensor for wet and dry waste classification, and a photoelectric sensor for metallic waste detection. Stepper and servo motors facilitate precise bin positioning and waste handling. The system is powered by a 12V DC source and programmed using embedded C through the Arduino IDE. Sensor inputs are processed to trigger motor actions and update the system's status. Notifications are sent through the ESP32 Wi-Fi module, which connects to a WhatsApp API for immediate alerts to waste management teams. Extensive testing was conducted to ensure accurate segregation and reliable communication.

The results indicate that the system successfully segregates waste into the specified categories with high precision. Ultrasonic sensors achieved a measurement accuracy of up to 0.1 cm, ensuring effective monitoring of waste levels. Metallic waste was consistently detected and prioritized, while the rain sensor reliably distinguished wet from dry waste. Notifications were promptly sent when bins exceeded the 5.5 cm capacity, enabling timely waste collection. The system demonstrated efficient and automated waste segregation with minimal human intervention, enhancing the recycling process.

**Nafiz, Das, Morol, Al Juabir and Nandi (2023, 10-11)** explore the development of ConvoWaste, an automatic waste segregation machine using deep learning and image processing techniques to enhance urban waste management and promote sustainability. The system classifies six types of waste: plastic, metal, glass, organic, medical, and e-waste, utilizing a deep convolutional neural network (DCNN) named ConvoWaste. Waste is placed on a conveyor belt where an ultrasonic sensor detects its presence, and a camera captures its image for classification. The classified waste is directed into corresponding bins using servo motors. The system also includes a GSM-based communication module to notify authorities about bin levels and integrates with an Android app for remote operation.

The methodology combines hardware and software components to achieve efficient waste segregation. A conveyor belt transports waste to a camera module, which captures images and sends them to the processing unit for classification using the ConvoWaste model. This model, a modified version of Inception-ResNet V2, incorporates additional layers for improved accuracy. The system uses a dataset of 12,000 images across six